



# LRFD

## Section 3.55

Revised: Aug. 2006

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**3.55.1 General**

**1.1 Material Properties**

**Concrete**

Standard compressive strength for P/S I-girder shall be:  $f'_{ci} = 4.5$  ksi  
 $f'_c = 6.0$  ksi

Optional concrete strength shall be:  $f'_{ci} = 5.0$  ksi  
 $f'_c = 7.0$  ksi

LRFD 5.4.2.4

Modulus of Elasticity,  $E_c = 33000K_1w_c^{1.5}\sqrt{f'_c}$

For  $f'_c \leq 5$  ksi,  $w_c = 0.145$  kcf

For  $f'_c > 5$  ksi,  $w_c = 0.140 + 0.001f'_c$

$K_1$  = correction factor for source of aggregate  
 = 1.0 unless determined by physical testing

**Prestressing strand**

LRFD 5.4.4.1

Type of strand:  
 AASHTO M203 (ASTM A416) Grade 270  
 Uncoated, seven-wire, low-relaxation strand

LRFD Table 5.4.4.1-1

Ultimate tensile strength,  $f_{pu} = 270$  ksi

LRFD Table 5.4.4.1-1

Yield strength,  $f_{py} = 0.9f_{pu}$  ksi

LRFD 5.4.4.2

Strand modulus of elasticity,  $E_p = 28500$  ksi

For standard concrete:

Strand diameter,  $d_{ps} = 0.5$ "

Strand area,  $A_{ps} = 0.153$  in<sup>2</sup>

For optional concrete:

Strand diameter,  $d_{ps} = 0.6$ "

Strand area,  $A_{ps} = 0.217$  in<sup>2</sup>

**Mild reinforcing steel**

LRFD 5.4.3.1

Minimum yield strength,  $f_y = 60.0$  ksi

LRFD 5.4.3.2

Steel modulus of elasticity,  $E_s = 29000$  ksi

# LRFD Bridge Design Guidelines

## Prestressed Concrete I-Girders – Section 3.55

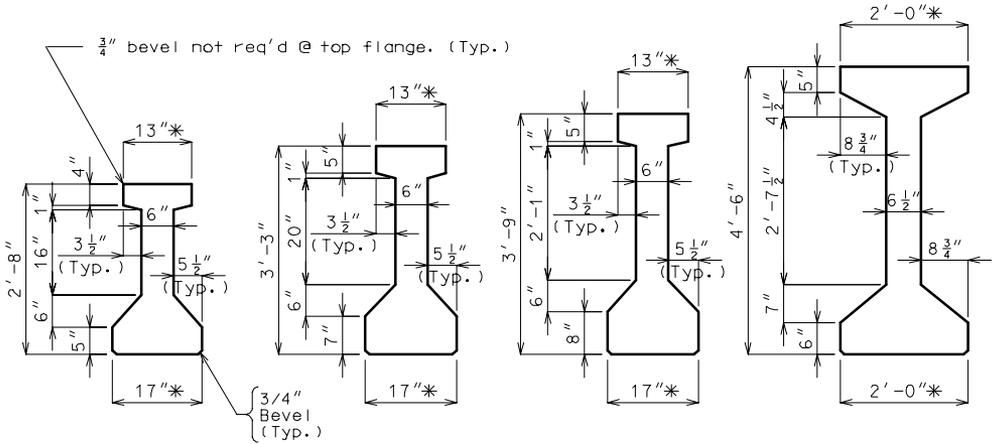
Page:1.2-1

### GEOMETRIC DIMENSIONS:

**General**

The ratio of the depth of girder to span length will in general be not less than 1/18.

The cross sectional dimensions of the girder will be one of the following:

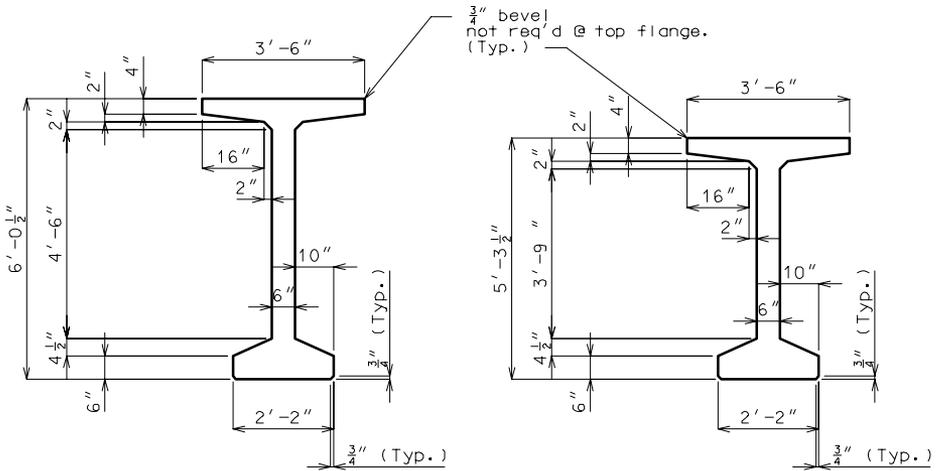


BEAM TYPE 2

BEAM TYPE 3

BEAM TYPE 4

BEAM TYPE 6



BEAM TYPE 7

BEAM TYPE 8

\* If the web is required to be increased, then the top and bottom flanges are to be increased by the same amount. (1" increments 2" max.).

# LRFD Bridge Design Guidelines

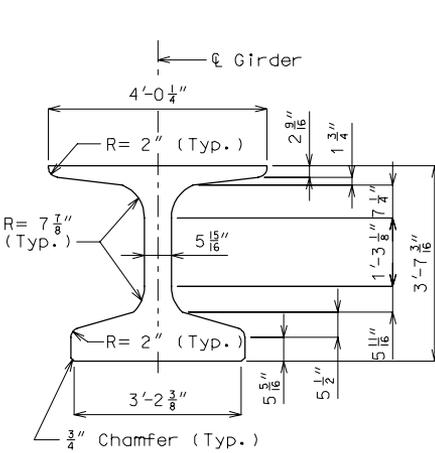
## Prestressed Concrete I-Girders - Section 3.55

Page:1.2-2

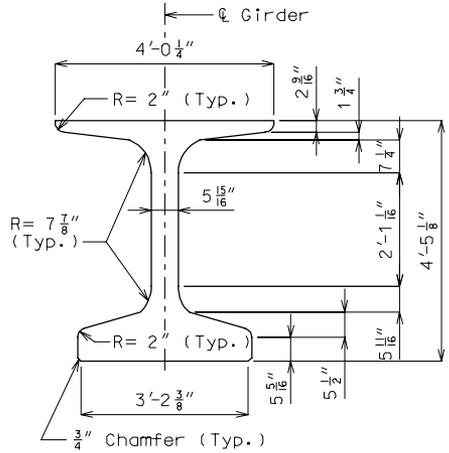
### GEOMETRIC DIMENSIONS:

**General**

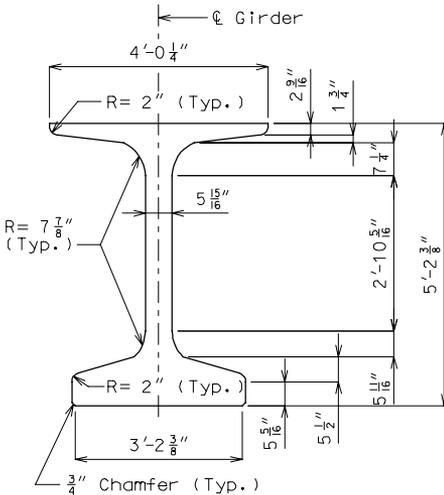
See Structural Project Manager before using Sections shown on this page.



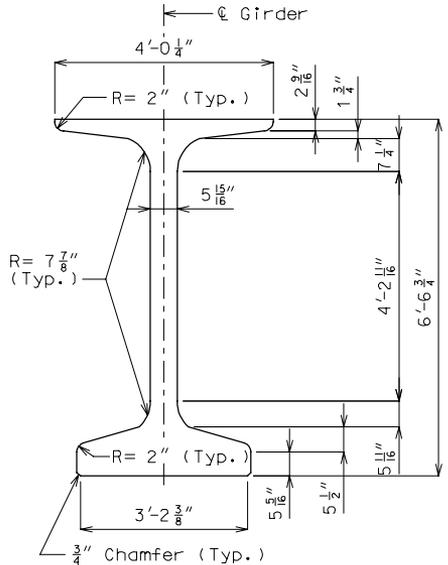
BEAM NU 43 (NU 1100)



BEAM NU 54 (NU 1350)



BEAM NU 63 (NU 1600)



BEAM NU 78 (NU 2000)

### **1.3 Typical Span Ranges**

The following charts are provided to assist in determining the span limitations of P/S I-girders.

#### **Standard concrete**

Criteria used in determining maximum span lengths for a conventional concrete are:

- 1) Low-relaxation strand with 0.5" strand diameter
- 2) Concrete strengths,  $f'_{ci} = 4.5$  ksi and  $f'_c = 6.0$  ksi
- 3) 3-span bridge consisting of 3 equal length girders made continuous and composite

#### **Optional concrete**

Criteria used in determining maximum span lengths for high performance concrete are:

- 1) Low-relaxation strand with 0.6" strand diameter
- 2) Concrete strengths,  $f'_{ci} = 5.0$  ksi and  $f'_c = 7.0$  ksi
- 3) 3-span bridge consisting of 3 equal length girders made continuous and composite

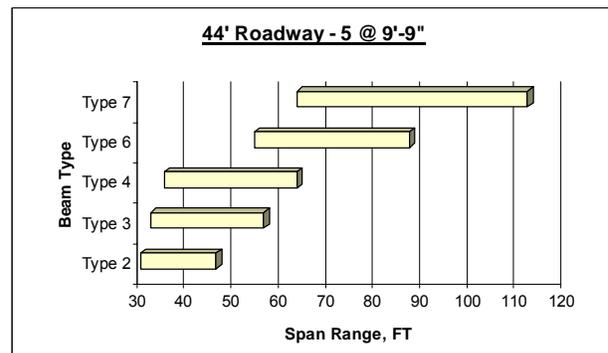
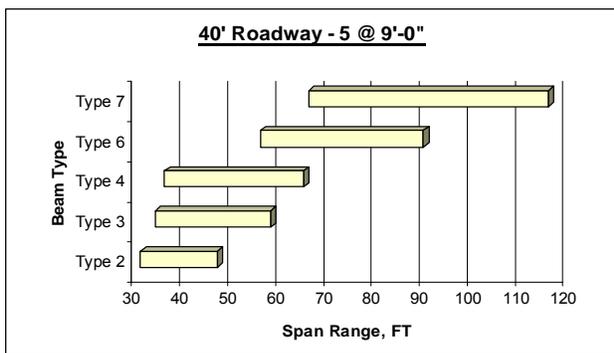
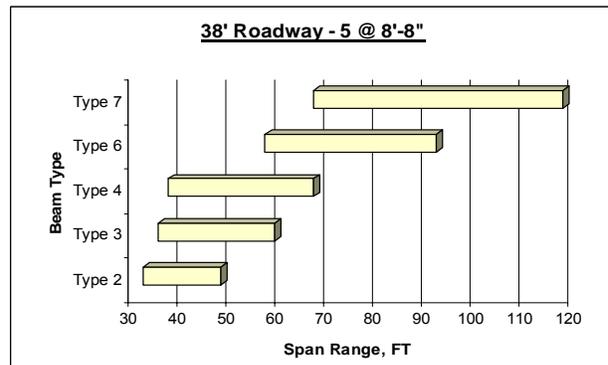
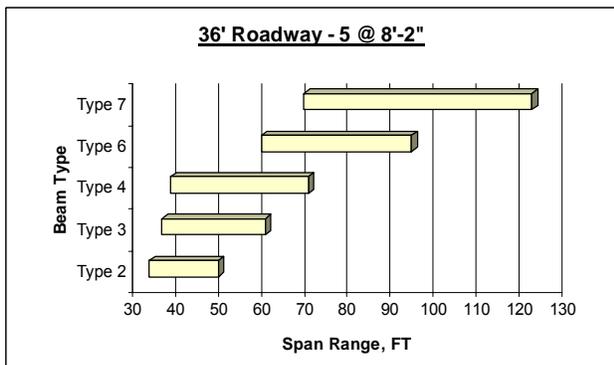
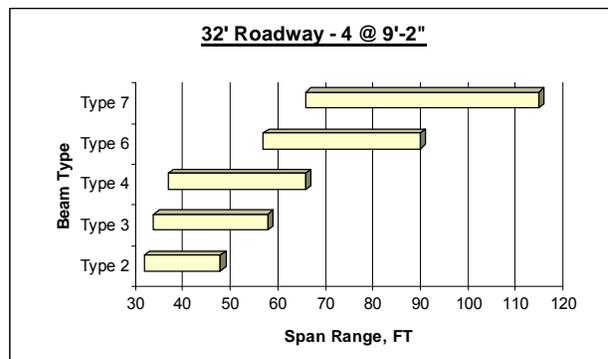
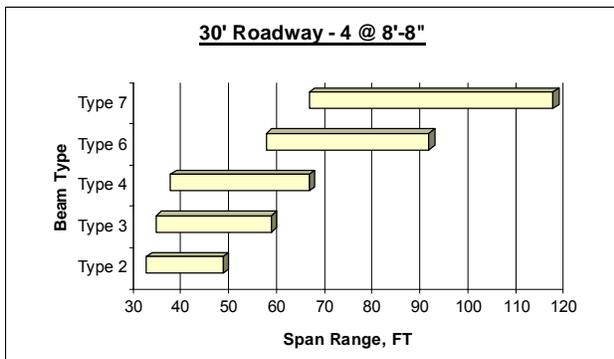
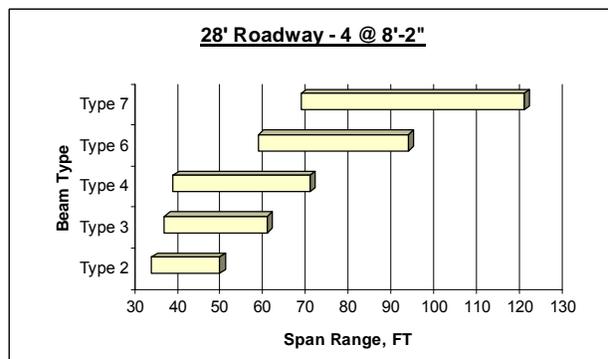
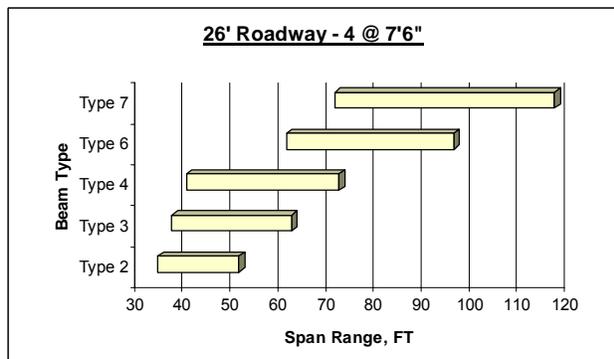
Minimum span lengths were determined by the positive moment capacity of the smallest strand arrangement per beam shape. Shorter span lengths are possible.

# LRFD Bridge Design Guidelines

## Prestressed Concrete I-Girders – Section 3.55

General

**Standard Concrete ( $f'_c = 6$  ksi) P/S I Beam Span Ranges for Given Roadway Widths and Girder Spacing**

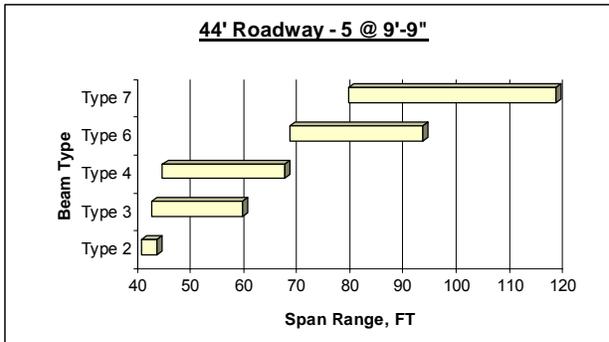
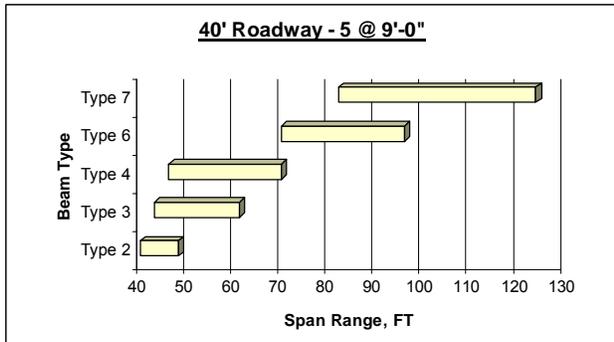
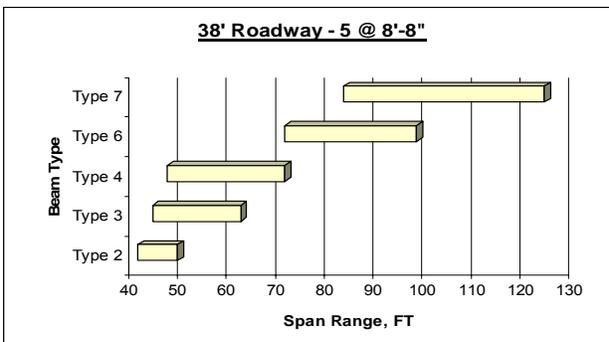
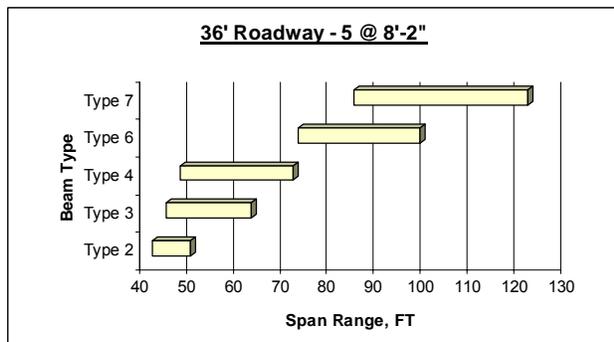
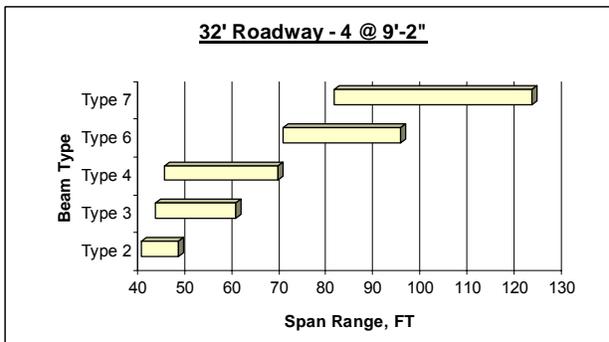
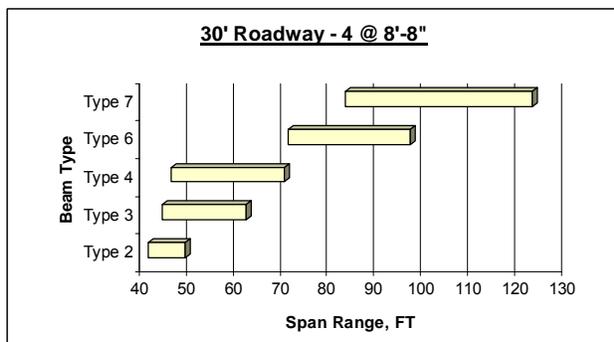
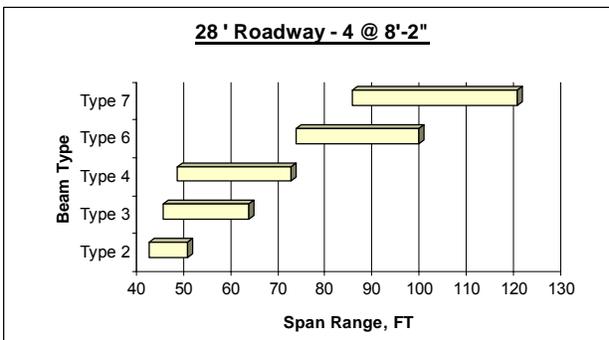
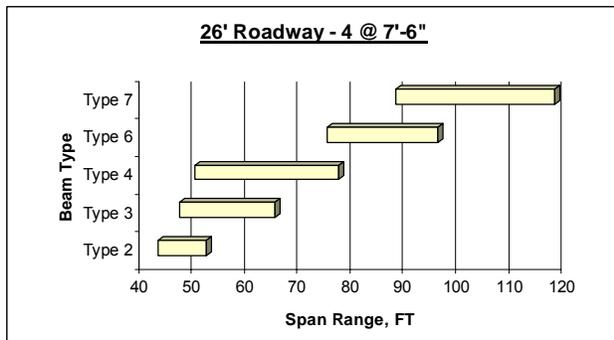


# LRFD Bridge Design Guidelines

## Prestressed Concrete I-Girders – Section 3.55

*General*

**Optional Concrete ( $f'_c = 7$  ksi) P/S I Beam Span Ranges for Given Roadway Widths and Girder Spacing**



### **1.4 Span and Structure Lengths**

#### ***Girder Length and Geometric Layout***

##### ***Tangent Bridges***

Girder lengths of exterior spans (i.e., end spans) shall be computed using the requirements shown on page LRFD DG Sec. 3.55.1.4-4 and, if possible, shall be the same length as girders in interior spans of equal length as specified on the Design Layout.

Girder lengths of interior spans shall be computed using the requirements shown on page LRFD DG Sec. 3.55.1.4-4.

##### ***Curved Bridges***

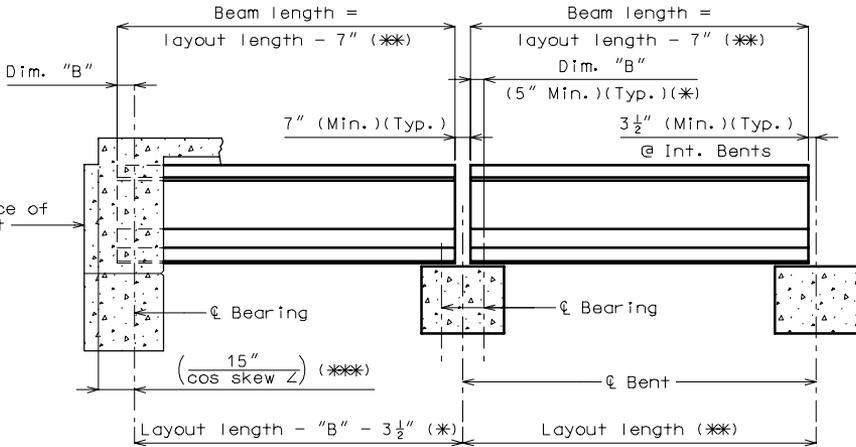
Layout of any curved structure may be done using any coordinate geometry programs available. To layout the bridge, use the following steps:

1. Start out by laying in the centerline (CL) of the survey curve.
2. Locate the tie point of the bridge. This point will usually be on the CL of the survey curve but may be on a baseline which is offset a certain distance to the CL of the survey curve.
3. A second tie point may be required if the skew is not measured to the CL of roadway at the bridge tie point. If this is the case, establish the tie point at the specified station and plot the skew line at the required angle.
4. Next, on the centerline of structure or baseline curve, locate the station of the CL of bent for each intermediate bent and the fill face for the end bents. Once these points are located, plot lines through these stations parallel to skew line. Normally the layout file will specify that all bents are parallel to the skew line; however, there may be times when the bents are radial or have varying skews.
5. When locating the stations in the preceding step, the distance between CL of intermediate bents are exactly the layout lengths specified on the file. However, the end spans need to follow the procedure for calculating length set forth in this section. If the layout length of the end span is the same as the interior spans, the length of the end span should be adjusted so that the girder lengths are, if possible, equal to interior spans with the same layout length.
6. When the CL of the intermediate bents and the fill face lines have been added, chords should be drawn connecting these points sequentially. For example, if you have a three span bridge, chords should be drawn from the fill face of bent 1 to CL of bent 2, CL bent 2 to CL bent 3, and CL bent 3 to fill face bent 4.

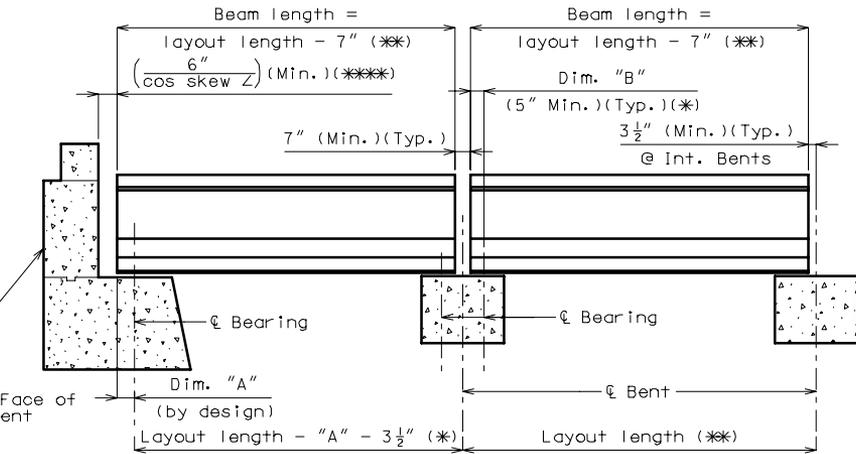
7. When all the chords are in, offset each girder in each span parallel to this chord. The perpendicular distance between girders will be the same for all spans, but the skew distance between girders along the bent will vary from bent to bent depending on the skew to the CL at that point. The designer needs to be aware of the fact that at an intermediate bent the distance between bearings on the approaching and leaving span sides will be different distances. These bearings will not line up across the bent and will actually diverge more the farther away they are from the CL of the survey.
8. When establishing the CL of bearing points, the designer needs to allow for a minimum of seven (7) inches between ends of girders at the bents while keeping in mind that the girders will be offset and at different skews. If the offset is greater than half the girder bottom flange width, see Structural Project Manager. The distance from the end of girder to CL of bearing point should be half of the bearing length plus one inch minimum clearance. Once the distance for CL bent to CL of bearing is calculated, the designer should offset lines by that dimension on either side of the CL of bent. These lines will then be intersected with each of the girder lines to create the bearing points on each bent.
9. Between the bearing points at the ends of the girders, quarter points or tenth points need to be established, depending on the girder span. These points will be used in calculating the haunch and bottom of slab elevations for the bridge deck.
10. The bridge deck and barrier curbs can be laid in by offsetting the CL of roadway to each side by the proper distance. Curves should be laid in to designate both the inside and outside edges of the barrier curb. These will later be useful in laying in the wings and end bents.
11. After the outside edge of slab curves are plotted, the curve offsets need to be found. The intersection point of the outside edge of slab and the CL of each bent or fill face can be connected with chords. The distance between these chords and their partner curves need to be calculated at five foot intervals beginning at the center point of each chord.
12. Joints are placed in the barrier curb at each bent. These joints are placed perpendicular to the CL of the roadway through the intersection point of the CL bent and the inside of barrier curb.
13. Wing layout length is given on the profile sheets in the layout file. An arc should be struck so as to intersect the inside of barrier curb the specified length from a point at the intersection of the fill face and the inside of barrier curb. This point will mark the end of the wing which is perpendicular to the CL of the roadway.

The vertical curve information needs to be added so a program can calculate the elevations at the desired stations. After this is done, the designer can request any of the following information which will be needed:

- Stations and elevations of all points
- Offset distances to the chords
- Lengths of girders
- Distances between bearings
- Angles between girders and each bent
- Lengths of bents
- Lengths of barrier curbs between joints
- Minimum vertical clearance



INTEGRAL END BENTS



NON-INTEGRAL END BENTS

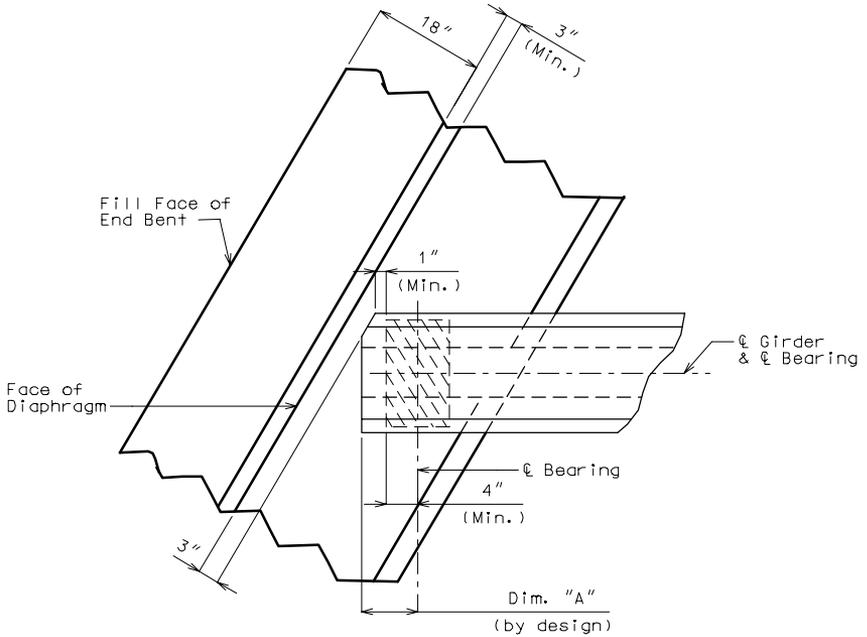
Note: Formulas assume same size bearing pads at end bent and intermediate bents.

(\*) Minimum dimension from edge of bearing pad to end of girder equals one inch.

(\*\*) Design layout lengths are horizontal lengths. Girder lengths should be adjusted according to grade and shall be specified to the nearest 1/4 inch.

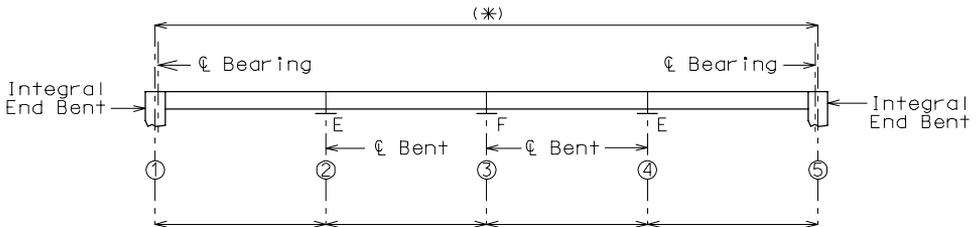
(\*\*\*) For large skews, end bent beam caps may need to be larger to provide edge distance.

(\*\*\*\*) Horizontal distance along centerline of girder. See Figure on the next page for details. Also, see LRFD DG Sec. 3.30 and 3.35 for minimum distance.



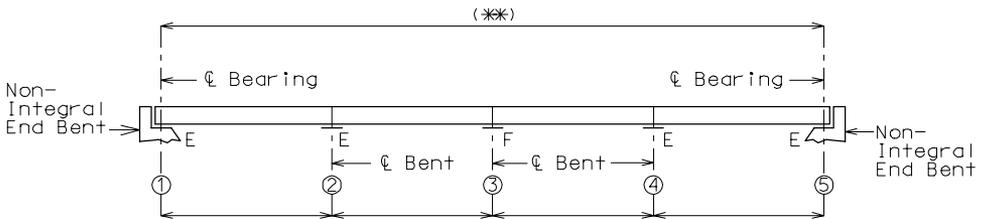
PART PLAN SHOWING COPING DETAIL

Note: Non-Integral end bents with skews greater than 40 degrees shall always have girder ends coped. Skews less than 40 degrees shall have girder ends coped on case by case basis. It is preferable to not cope across the web.



(\* ) Maximum length from End Bent to End Bent = 600 feet.

TYPICAL CONTINUOUS PRESTRESS STRUCTURE  
(INTEGRAL END BENTS)



(\*\*) Maximum length from End Bent to End Bent = 800 feet.

TYPICAL CONTINUOUS PRESTRESS STRUCTURE  
(NON-INTEGRAL END BENTS)

### **1.5 Constant and Varied Joint Filler Loads**

#### ***Varied joint filler load***

The prestressed I-girder should first be designed assuming that the contractor will vary the joint filler supporting the panels on the girder flange. This assumption will maintain the minimum slab/panel combination thickness of 8 1/2", and will eliminate the possibility of increased load due to varying slab thickness.

#### ***Constant joint filler load***

With the girder designed and the camber and haunching dimensions calculated, the girder should be checked assuming the contractor will use a constant 1" joint filler. This will cause the slab thickness to vary due to camber of the girder, increasing load. This additional load shall be placed as a concentrated load at 1/8 point from each end of the girder.

An example of how this concentrated load could be calculated is shown as follows:

$$\text{Load } w = (A)(0.15 \text{ kips/ft.}^3)$$

Determine the concentrated load\* to girders by distributing  $w$  transversely across the girders. If the minimum haunch is greater than 1" joint filler, the additional haunch shall be included in the slab thickness as a uniform load. If the use of these loads causes the girder design to change, it shall be the responsibility of the designer to determine if the camber and haunching should be recalculated.

\*This load shall be positioned at the 1/8 point from centerline of bearing pad.

The girder and bearing designs should be checked for the constant joint filler option and constant joint filler load. However, camber, haunching and beam seat elevations shown on the plans should be based on the variable joint filler option.

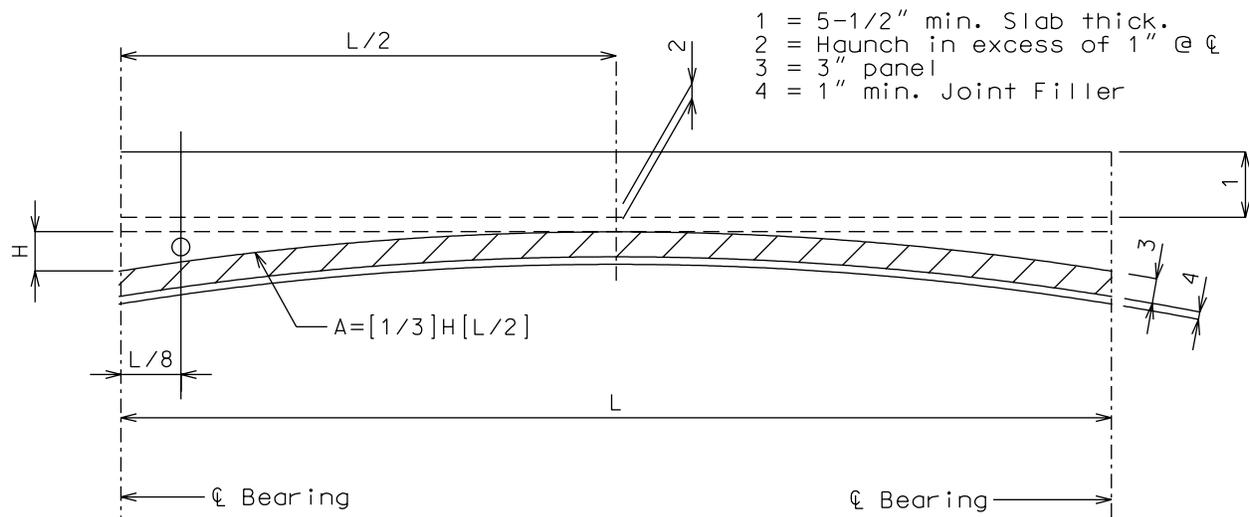


Figure 3.55.1.1 Joint filler loads

**3.55.2 Design****2.1 Load Combinations**

In general, each component shall satisfy the following equation:

LRFD 1.3.2.1 
$$Q = \sum \eta_i \gamma_i Q_i \leq \phi R_n = R_r$$

Where:

Q = Total factored force effect

$Q_i$  = Force effect

$\eta_i$  = Load modifier

$\gamma_i$  = Load factor

$\phi$  = Resistance factor

$R_n$  = Nominal resistance

$R_r$  = Factored resistance

LRFD 5.5

**Limit states**

The following limit states shall be used for P/S Girder design.

LRFD Table 3.4.1-1

SERVICE I - for compressive stress

SERVICE III - for tensile stress

LRFD 5.5.4

**STRENGTH I**

See LRFD Table 3.4.1-1 for Loads and Load Factors applied at each given limit state.

LRFD 5.5.4.2.1

**Resistance factor,  $\phi$** 

LRFD 6.5.4.2

STRENGTH limit states, see LRFD Article 6.5.4.2 & 5.5.4.2.1

LRFD 1.3.2.1

For all other limit states,  $\phi = 1.00$

LRFD 1.3.2.1

**Load modifiers,  $\eta$** 

For loads for which a maximum value of load factor,  $\gamma$ , is appropriate,

$$\eta = (\eta_I \eta_R \eta_D) \geq 0.95$$

For loads for which a minimum value of load factor,  $\gamma$ , is appropriate,

$$\eta = 1 / (\eta_I \eta_R \eta_D) \leq 1.0$$

Where:

$\eta_D$  = Factor relating to ductility

$\eta_R$  = Factor relating to redundancy

$\eta_I$  = Factor relating to operational importance. See Structural Project Manager for values other than the one shown in Table 3.55.2.1.

Load modifiers in Table 3.55.2.1 shall be used for all P/S I-girder design.

**Table 3.55.2.1.1 Load modifiers**

	All Limit States
Ductility, $\eta_D$	1.0
Redundancy, $\eta_R$	1.0
Operational importance, $\eta_I$	1.0
$\eta = (\eta_I \eta_R \eta_D)$	1.0
$\eta = 1 / (\eta_I \eta_R \eta_D)$	1.0

**2.2 Prestressing Strands**

**Transfer Length of Prestressing Strands**

The prestressing force may be assumed to vary linearly from zero at the point where bonding commences to a maximum at the transfer length. The transfer length may be taken as 60 times the strand diameter.

**Development Length of Prestressing Strands**

LRFD 5.11.4.2

The development length for prestressing strands shall be taken as:

$$l_d \geq 1.6 \left( f_{ps} - \frac{2}{3} f_{pe} \right) d_{ps}$$

Where:

$d_{ps}$  = Nominal diameter of strand, (in.)

$f_{ps}$  = Average stress in prestressing strand at the time for which the nominal resistance of the girder is required, (ksi)

LRFD 5.9.3

**Stress limits for prestressing strands**

Strand stress at service limit state shall not exceed the following:

At jacking:

$$f_{pj} \leq 0.75 f_{pu} \text{ ksi}$$

(For typical girders and fabrication economy,  $f_{pj} = 0.75 f_{pu}$ )

At service limit state after all losses:

$$f_{pe} \leq 0.80 f_{py} \text{ ksi}$$

Where:

$f_{pj}$  = Stress in prestressing strand at jacking, (ksi)

$f_{pe}$  = Effective stress of strand after all losses, (ksi)

$f_{py}$  = Yield strength of strand, (ksi)

$f_{pu}$  = Ultimate tensile strength of strand, (ksi)

**Prestress Losses**

Refined estimates of time-dependent losses are used, based on AASHTO LRFD Article 5.9.5.4, as opposed to approximate lump sum estimate of losses in AASHTO LRFD Article 5.9.5.3.

The prestress losses shall be calculated to investigate concrete stresses at two different stages.

- 1) Temporary stresses immediately after transfer:
- 2) Final stresses

The prestress loss for temporary stress checks is:

$$\Delta f_{pI} = \Delta f_{pES} + \Delta f_{pSR} + \Delta f_{pCR} + \Delta f_{pR1}$$

The prestress loss for final stress checks

LRFD 5.9.5.1

$$\Delta f_{pT} = \Delta f_{pI} + \Delta f_{pSD} + \Delta f_{pCD} + \Delta f_{pR2} - \Delta f_{pSS}$$

Where:

$\Delta f_{pI}$  = Initial loss of prestress, ksi

$\Delta f_{pT}$  = Total loss of prestress, ksi

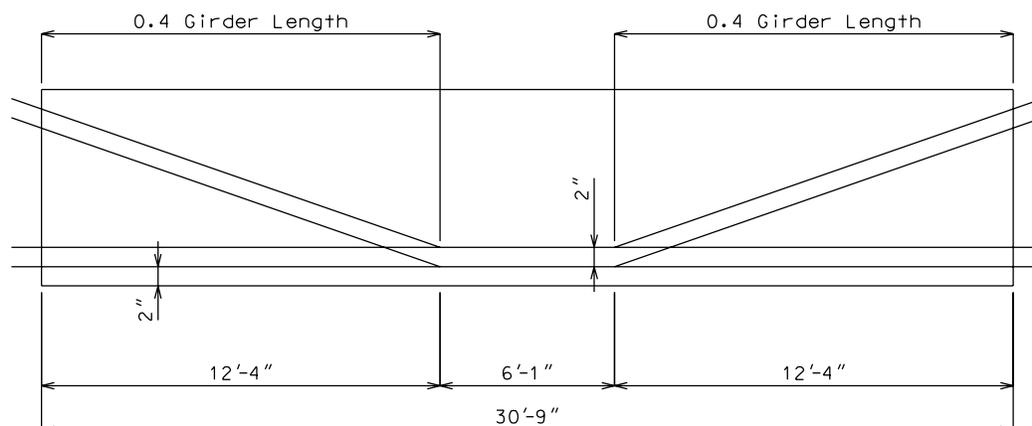
- $\Delta f_{pES}$  = Loss due to elastic shortening, ksi
- $\Delta f_{pSR}$  = Loss due to shrinkage between transfer and deck placement, ksi
- $\Delta f_{pCR}$  = Loss due to creep between transfer and deck placement, ksi
- $\Delta f_{pR1}$  = Loss due to relaxation of strand between time of transfer and deck placement, ksi
- $\Delta f_{pR2}$  = Loss due to relaxation of strand between deck placement and final time, ksi
- $\Delta f_{pSD}$  = Loss due to shrinkage of girder between deck placement and final time, ksi
- $\Delta f_{pCD}$  = Loss due to creep of girder between deck placement and final time, ksi
- $\Delta f_{pSS}$  = Loss due to shrinkage of deck composite section, ksi

SERVICE I and SERVICE III Limit states shall be investigated at each stage.

**Harped Strands**

Harped strands, although they add to the shear strength of the girder, are primarily used to keep the girder stresses (both top and bottom) within allowable limits while developing the full capacity of the girder at midspan.

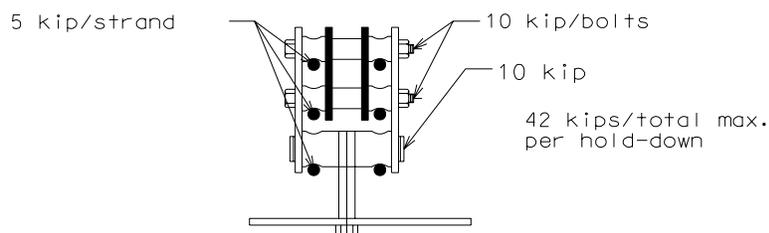
Harped strands should be held down at points of 0.4 of the distance from each end of the girder.



**Figure 3.55.2.2.1 Example Harped Strand Layout**

The jacking force applied to prestress strands produces an excessive vertical uplift in short spans on tall girders resulting in failure of harped strand hold-downs. The allowable limits for hold-downs are as follows.

- 1) 5 kip/strand
- 2) 10 kip/bolt
- 3) 42 kip/hold-down



**Figure 3.55.2.2.2 Hold-Down Device**

If necessary, lower harped strand end location to meet criteria or use straight strands.

Short spans (< 40') are to use straight strands for all girders greater than 2'-8" tall. Use at least two straight strands at the top of the girder when straight strands are used. Where straight strands will not work a single hold-down point may be used. Note: A single point hold-down has twice the uplift force.

Investigate the possibility of using all straight strands when strength check of a hold-down device exceeds allowable.

#### ***Debonding Strands***

In all debonding operations the prestressing forces must be in such a manner as to prevent any sudden or shock loading.

**2.3 Flexure**

Flexure capacity of prestressed I-girders shall be determined as the following.

**Flexural resistance at strength limit state**

LRFD 5.7.3.2.1

$$M_r = \phi M_n \geq M_u$$

Where:

$M_r$  = Flexural resistance

$M_n$  = Nominal flexural resistance

$M_u$  = Total factored moment from Strength I load combination

$\phi$  = Flexural resistance factor  
1.0 for Prestressed Concrete  
0.9 for Reinforced Concrete

**Negative moment reinforcement design**

P/S I-girder shall be designed as a reinforced concrete section at regions of negative flexure (i.e., negative moment).

LRFD 5.11.1.2.3

At least one-third of the total tensile reinforcement provided for negative moment at the support shall have an embedment length beyond the point of inflection not less than the specified development length of the bars used.

LRFD 5.14.1.2.7b

Slab longitudinal reinforcement that contributes to making the precast beam continuous over an intermediate bent shall be anchored in regions of the slab that can be shown to be crack-free at strength limit states. This reinforcement anchorage shall be staggered. Regular longitudinal slab reinforcement may be utilized as part of the total longitudinal reinforcement required.

**Design A1 bar in the top flange**

LRFD 5.9.4.1

The reinforcement A1 shall resist the tensile force in a cracked section computed on the basis of an uncracked section.

Required steel area is equal to:

$$A1 = \frac{T_t}{f_s}$$

Where:

$f_s$  =  $0.5f_y \leq 30$  KSI, allowable tensile stress of mild steel, (ksi)

$T_t$  = Resultant of total tensile force computed on the basis of an uncracked section, (kips)

LRFD 5.7.3.3

#### **Limits for reinforcement**

The following criteria shall be considered only at composite stage.

LRFD 5.7.3.3.1

Maximum amount of prestressed and non-prestressed reinforcement shall be such that:

$$\frac{c}{d_e} \leq 0.42$$

$$d_e = \frac{A_{ps} f_{ps} d_p + A_s f_y d_s}{A_{ps} f_{ps} + A_s f_y}$$

Where:

$c$  = Distance from extreme compression fiber to neutral axis, (in.)

$d_e$  = Distance from extreme compression fiber to the centroid of tensile force in the tensile reinforcement, (in.)

$d_p$  = Distance from extreme compression fiber to centroid of prestressing strands, (in.)

$d_s$  = Distance from extreme compression fiber to a centroid of non-prestressed tensile reinforcement, (in.)

$A_s$  = Total area of tension steel, (in.<sup>2</sup>)

$A_{ps}$  = Total area of strands, (in.<sup>2</sup>)

$f_y$  = Minimum yield strength of tension steel, (ksi)

$f_{ps}$  = Average stress in prestressing strand, (ksi)

Note: A section is considered over-reinforced if  $(c/d_e) > 0.42$  which shall not be permitted.

LRFD 5.7.3.3.2

Minimum amount of prestressed and non-prestressed tensile reinforcement shall be such that the factored flexural resistance,  $M_r$ , is at least equal to the lesser of:

- $1.2M_{cr}$ , or
- $1.33M_u$

Where:

$M_{cr}$  = Cracking moment, (kip-in.)

$M_u$  = Total factored moment from Strength I load combination, (kip-in.)

**2.4 Shear**

Shear capacity of P/S I-girder should be checked along girder length and girder-slab interface.

**Shear resistance at strength limit state**

LRFD 5.8.2.1

$$V_r = \phi V_n \geq V_u$$

Where:

$V_r$  = Shear resistance

$V_n$  = Nominal shear resistance

$V_u$  = Total factored shear from Strength I load combination

$\phi$  = Shear resistance factor

LRFD 5.8.3.3

**Nominal shear resistance**

The nominal shear resistance,  $V_n$ , shall be lesser of:

- $V_c + V_s + V_p$ , or
- $0.25f'_c b_v d_v + V_p$

Where:

$$V_c = 0.0316\beta b_v d_v \sqrt{f'_c}$$

$$V_s = \frac{A_v f_y d_v (\cot \theta + \cot \alpha) \sin \alpha}{s}$$

Where:

$V_c$  = Nominal concrete shear resistance, (kips)

$V_s$  = Nominal shear reinforcement resistance, (kips)

$V_p$  = Component of prestressing force in the direction of shear force, (kips)

$b_v$  = Thickness of web, (in.)

$d_v$  = Effective shear depth taken as the distance measured perpendicular to the neutral axis, between the resultants of tensile and compressive forces due to flexure, (in.)

$s$  = Spacing of shear reinforcement, (in.)

LRFD 5.8.3.4.1

$\beta$  = Factor indicating ability of diagonally cracked concrete to transmit tension

LRFD 5.8.3.4.1

$\theta$  = Angle of inclination of diagonal compressive stress, (degree)

$\alpha$  = 90.0, Angle of inclination of shear reinforcement to a longitudinal axis, (degree)

$A_v$  = Area of shear reinforcement, (in.<sup>2</sup>)

$f_y$  = Minimum yield strength of tension shear reinforcement, (ksi)

LRFD 5.8.3.2

**Design sections near supports**

Where a reaction force in the direction of the applied shear introduces compression into the end region of girder, the location of the critical section for shear is measured from the internal face of support a distance,  $d_v$ . Otherwise, the design section shall be taken at the internal face of the support.

Where:

LRFD 5.8.2.9

$d_v$  = effective shear depth taken as the distance, measured perpendicular to the neutral axis, between the resultants of the tensile and compressive forces due to flexure; it need not be taken to be less than the greater of  $0.9d_e$  and  $0.72h$ .

LRFD 5.8.2.4

**Girder regions requiring shear reinforcement**

Girder shear reinforcement, usually consisting of stirrups, shall be provided where:

$$V_u > 0.50\phi(V_c + V_p)$$

Where:

$V_u$  = Factored shear force from Strength I load combination, (kips)

$V_c$  = Nominal concrete shear resistance, (kips)

$V_p$  = Component of prestressing force in the direction of shear force, (kips)

$\phi$  = Shear resistance factor  
= 0.9 for normal weight concrete

**Shear Reinforcement Limits**

**Minimum reinforcement**

LRFD 5.8.2.5

Area of shear reinforcement shall not be less than:

$$A_v \geq 0.0316 \left( \frac{b_v s}{f_y} \right) \sqrt{f'_c}$$

Where:

$A_v$  = Area of shear reinforcement, (in.<sup>2</sup>)

$b_v$  = Thickness of web, (in.)

$s$  = Spacing of shear reinforcement, (in.)

$f'_c$  = Final concrete compressive strength, (ksi)

#### Maximum reinforcement

LRFD 5.8.2.7

Maximum spacing of shear reinforcement shall be determined as:

$$\text{If } v_u < 0.125f'_c, \text{ then } s_{max} = 0.8d_v \leq 24.0''$$

$$\text{If } v_u \geq 0.125f'_c, \text{ then } s_{max} = 0.4d_v \leq 12.0''$$

Where:

$d_v$  = Effective shear depth taken as the distance measured perpendicular to the neutral axis, between the resultants of tensile and compressive forces due to flexure, (in.)

$v_u$  = Shear stress on concrete, (ksi)

$s_{max}$  = Maximum spacing of shear reinforcement, (in.)

LRFD 5.8.2.9

Shear stress on concrete shall be determined as:

$$v_u = \frac{V_u - \phi V_p}{\phi b_v d_v}$$

$$d_v = \left( d_e - \frac{a}{2} \right) \geq \text{larger of } \begin{cases} 0.9d_e \\ 0.72h \end{cases}$$

Where:

$v_u$  = Shear stress on concrete, (ksi)

$V_u$  = Factored shear from Strength I load combination, (kips)

$\phi$  = Shear resistance factor  
= 0.9 for normal weight concrete

$b_v$  = Thickness of web, (in.)

$V_p$  = Component of prestressing force in the direction of shear force, (kips)

$d_v$  = Effective shear depth taken as the distance measured perpendicular to the neutral axis, between the resultants of tensile and compressive forces due to flexure, (in.)

$$= \frac{M_n}{A_s f_y + A_{ps} f_{ps}}$$

$d_e$  = Distance from extreme compression fiber to the centroid of tensile force in the tensile reinforcement, (in.)

$h$  = Total height of girder including slab thickness, (in.)

LRFD 5.8.1.3

#### **Girder-Slab Interface**

The horizontal shear between the girder and slab shall be determined as:

LRFD C5.8.4.1

$$V_h = \frac{V_u}{d_e}$$

Where:

$V_u$  = Factored shear force from Strength I load combination, (kips)

$V_h$  = Factored horizontal shear, (kips)

$d_e$  = Distance from centroid of girder's tensile strands (and steel) to center of compression block (i.e.,  $d - a/2$ ) or mid-depth of slab, (in.)

LRFD 5.8.4.1

Nominal horizontal shear resistance of interface plane shall be taken as:

$$V_n = cA_{cv} + \mu(A_{vf}f_y + P_c) \leq \text{smaller of } \begin{cases} 0.2f'_cA_{cv} \\ 0.8A_{cv} \end{cases}$$

Minimum shear reinforcement of interface plane shall be:

$$A_{vf} \geq \frac{0.05b_{vf}}{f_y}$$

Where:

LRFD 5.8.4.2

$c$  = 0.1 ksi, Cohesion factor

LRFD 5.8.4.2

$\mu$  = 1.0, Friction factor for normal weight concrete

$P_c$  = Permanent net compressive force normal to shear plane; if the force is tensile,  $P_c = 0.0$ , (kips)

$A_{cv}$  = Area of concrete engaged in shear transfer, (in.<sup>2</sup>)

$A_{vf}$  = Area of shear reinforcement crossing shear plane, (in.<sup>2</sup>)

$b_{vf}$  = Width of the interface, (in.)

$f_y$  = Minimum yield strength of mild steel reinforcement, (ksi)

LRFD 5.8.4.1

Note: The minimum requirement of reinforcement,  $A_{vf}$ , may be waived if  $(V_n / A_{cv}) < 0.10$  ksi. Longitudinal spacing of rows of reinforcing bars shall not exceed 24". If the width,  $b_{vf}$ , exceeds 48.0", a minimum of four bars should be used for each row.

LRFD 5.8.3.5

**Longitudinal Tensile Reinforcement**

At each section, the tensile capacity of the longitudinal reinforcement on the flexural tension side of the member shall be proportioned to satisfy:

$$A_s f_y + A_{ps} f_{ps} \geq \frac{|M_u|}{\phi_f d_v} + 0.5 \frac{N_u}{\phi_c} + \left( \left| \frac{V_u}{\phi_v} - V_p \right| - .5V_s \right) \cot \theta$$

Where:

$M_u$  = Factored moment from Strength I load combination, (kip-in.)

$N_u$  = Factored axial force from Strength I load combination, (kips)

$V_u$  = Factored shear from Strength I load combination, (kips)

$V_s$  = Nominal shear resistance provided by shear reinforcement, and shall not be taken greater than  $(V_u/\phi)$ , (kips)

$V_p$  = Component of prestressing force in the direction of shear force, (kips)

$d_v$  = Effective shear depth taken as the distance measured parallel to the neutral axis, between the resultants of tensile and compressive forces due to flexure, (in.)

$A_{ps}$  = Total area of strands, (in.<sup>2</sup>)

$A_s$  = Total area of tension steel, (in.<sup>2</sup>)

$f_y$  = Minimum yield strength of mild steel reinforcement, (ksi)

$f_{ps}$  = Average stress in prestressing strand at the time for which the nominal resistance of the girder is required, (ksi)

$\phi$  = Resistance factors for moment (f), shear (v), and axial resistance (c) as appropriate

LRFD 5.8.3.4.1

$\theta$  = 45.0, Angle of inclination of diagonal compressive stress, (degree)

LRFD 5.10.10

**Pretensioned anchorage zones**

The bursting resistance of anchorage zones provided by vertical reinforcement (i.e., B2 bars) in the ends of prestressed girders at the service limit state shall be taken as:

LRFD 5.10.10.1

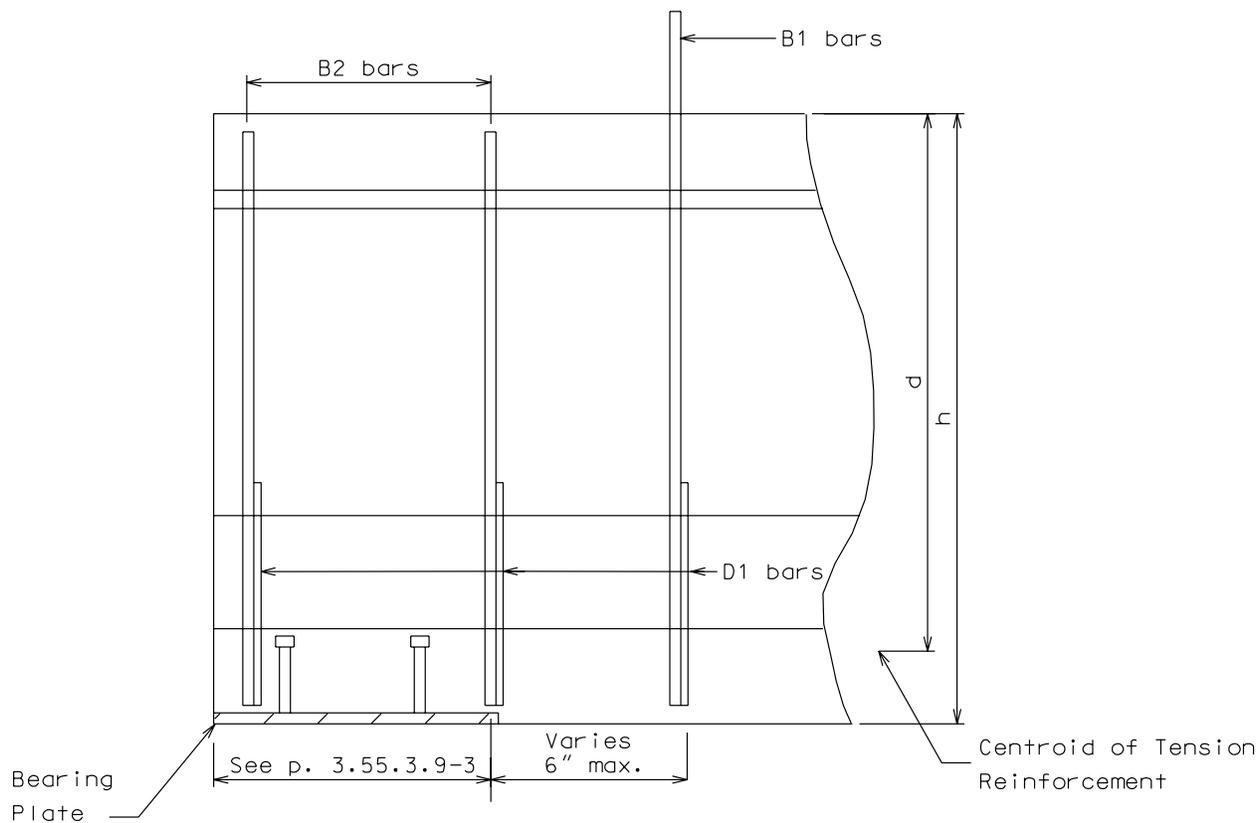
$$P_r = f_s A_s \geq 0.04 F_{po}$$

Where:

$f_s$  = Stress in mild steel not exceeding 20 ksi

$A_s$  = Total area of vertical reinforcement located within a minimum distance of  $h/4$  from the end of the girder where  $h$  is overall depth of precast member as shown in Figure 3.55.2.1.

$F_{po}$  = Prestressing force at transfer



**Figure 3.55.2.1 Anchorage Zone and Confinement Reinforcement**

LRFD 5.10.10.2

**Confinement reinforcement**

Reinforcement (i.e., D1 bars) shown in Figure 3.55.2.1 shall be placed to confine the prestressing strands in the bottom flange for a minimum distance of  $1.5d$  from the end of beam.

The reinforcement shall not be less than #4 deformed bar, with spacing not exceeding 6.0 inches and shaped to enclose the strands.

LRFD 5.7.3.6

LRFD 2.5.2.6.2

**2.5 Deformations****Criteria for deflection**

For investigating maximum absolute deflection, all design lanes shall be loaded, and all supporting components should be assumed to deflect equally.

For composite design, the design cross-section should include the entire width of the roadway and the structurally continuous portions of railings, sidewalks, and median barriers. Note that safety barrier curbs are usually discontinuous over the bents. For skewed bridges, a right cross-section may be used.

LRFD 2.5.2.6.2 &amp; 3.6.1.3.2

Service I load combination shall be used. Dynamic load allowance shall be applied.

**Live Load Deflection Limits**

See LRFD DG Sec. 1.2.4.2 for live load deflection criteria.

LRFD 5.7.3.6.2

**Calculation of deflection and camber**

Deflection and camber calculations shall consider all internal loads (i.e., prestressing, concrete creep, and shrinkage) and external loads such as dead loads and live loads.

Camber is an upward displacement caused by moment due to prestressing forces. Deflection is a downward displacement due to external loads. Therefore, both camber and deflection shall be considered in making an appropriate adjustment for final profile grade on the bridge.

**Initial camber at midspan**

Total initial camber at transfer due to self-weight of girder and prestressing forces shall be determined as:

$$\Delta_{IC} = (1 + \psi)(\Delta_g - \Delta_{SS} - \Delta_{HS})$$

Where:

$\Delta_{IC}$  = Initial camber at transfer

$\Delta_g$  = Deflection due to self-weight of girder

$\Delta_{SS}$  = Camber due to prestressing straight strands

$\Delta_{HS}$  = Camber due to prestressing harped strands

$\psi$  = Creep coefficient prior to casting slab deck

Note: Positive and negative values indicate downward and upward displacements, respectively.

**Final camber at midspan**

Total deformation can be determined as the sum of initial camber and deflections due to slab, diaphragm, and creep effect before composite action between slab and girder.

$$\Delta_T = \Delta_{IC} + \Delta_S + \sum \Delta_C$$

Where:

$\Delta_C$  = Deflection due to concentrated loads

$\Delta_S$  = Deflection due to self-weight of slab

**Final camber along span length**

Deformations along the span length can be approximately determined as a product of final camber at midspan times correction factors.

$$\Delta_{0.10} = 0.3140\Delta_T \text{ at span fraction of 0.10}$$

$$\Delta_{0.20} = 0.5930\Delta_T \text{ at span fraction of 0.20}$$

$$\Delta_{0.25} = 0.7125\Delta_T \text{ at span fraction of 0.25}$$

$$\Delta_{0.30} = 0.8130\Delta_T \text{ at span fraction of 0.30}$$

$$\Delta_{0.40} = 0.9520\Delta_T \text{ at span fraction of 0.40}$$

$$\Delta_{0.50} = 1.0000\Delta_T \text{ at span fraction of 0.50}$$

**Calculation of camber (upward)**

Camber at midspan due to strand forces is determined as the following:  
For straight strands,

$$\Delta_{SS} = \frac{F_1 e_1 L^2}{8E_{ci} I_{TN}}$$

Where:

$F_1$  = Total prestressing force of straight strands at transfer (including losses due to elastic shortening and initial strand relaxation), (kips)

$L$  = Distance between centerlines of bearing pads, (in.)

$E_{ci}$  = Initial concrete modulus of elasticity based on  $f'_{ci}$ , (ksi)

$I_{TN}$  = Moment of inertia of transformed non-composite section computed based on  $E_{ci}$ , (in.<sup>4</sup>)

$e_1$  = Eccentricity between centroid of straight strands (CSS) and center of gravity of transformed non-composite section (CGB) as shown in Figure 3.55.2.2, (in.)

For two-point harped strands,

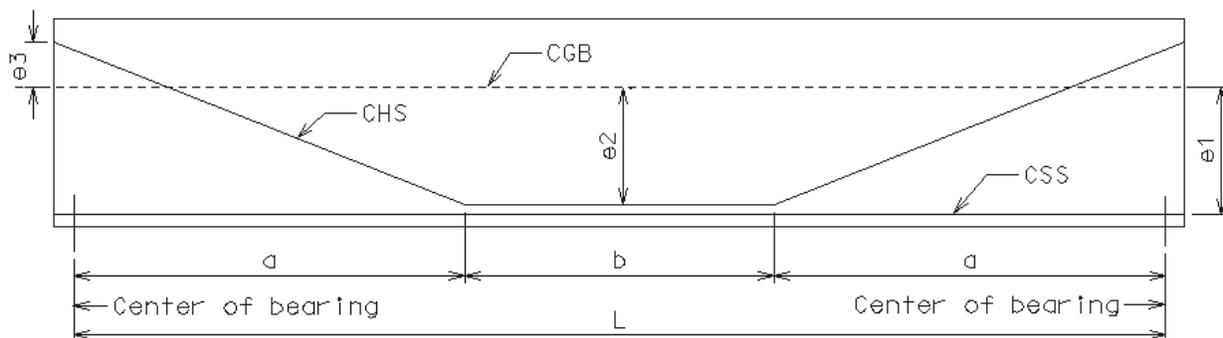
$$\Delta_{HS} = \frac{F_2 e_2 L^2}{8E_{ci} I_{TN}} - \frac{F_2 (e_2 + e_3) a^2}{6E_{ci} I_{TN}}$$

$$a = (L - b)/2$$

Where:

$F_2$  = Total prestressing force of harped strands at transfer (including losses due to elastic shortening and initial strand relaxation), (kips)

- $b$  = Length between harped points, (in.)
- $e_2$  = Eccentricity between centroid of harped strands (CHS) and center of gravity of transformed non-composite section (CGB) at midspan as shown in Figure 3.55.2.2, (in.)
- $e_3$  = Eccentricity between centroid of harped strands (CHS) and center of gravity of transformed non-composite section (CGB) at the end of girder as shown in Figure 3.55.2.2, (in.)



**Figure 3.55.2.2 Details of girder showing distances and eccentricities used in camber calculations.**

***Calculations of deflections (downward)***

Deflections at midspan due to dead loads are determined as the following:

For self-weight of girder,

$$\Delta_g = \frac{5W_g L^4}{384E_{ci} I'_{TN}}$$

Where:

$W_g$  = Uniform load due to self-weight of girder, (kip/in.)

For self-weight of slab,

$$\Delta_s = \frac{5W_s L^4}{384E_c I'_{TN}}$$

Where:

$W_s$  = Uniform load due to self-weight of slab, (kip/in.)

$E_c$  = Concrete modulus of elasticity based on  $f'_c$ , (ksi)

$I'_{TN}$  = Moment of inertia of transformed non-composite section computed based on  $E_c$ , (in.<sup>4</sup>)

Weight of additional slab haunch may be treated as uniform or concentrated load as appropriate. Diaphragm weight should be treated as concentrated load.

For one concentrated load at midspan,

$$\Delta_c = \frac{PL^3}{48E_c I'_{TN}}$$

For two equal concentrated loads,

$$\Delta_c = \frac{Px}{24E_c I'_{TN}} (3L^2 - 4x^2)$$

Where:

- $P$  = Concentrated load due to diaphragm and/or additional slab haunch, (kips)  
 $x$  = Distance from the centerline of bearing pad to the applied load,  $P$ , (in.)

LRFD 5.4.2.3.2

### Creep coefficient

Research has indicated that high strength concrete (HSC) undergoes less ultimate creep and shrinkage than conventional concrete.

Creep is a time-dependent phenomenon in which deformation increases under a constant stress. Creep coefficient is a ratio of creep strain over elastic strain, and it can be estimated as follows:

$$\Psi(t, t_i) = 1.9k_s k_{hc} k_f k_{td} t_i^{-0.118}$$

$$k_s = 1.45 - 0.13(v/s) \geq 1.0$$

$$k_{hc} = 1.56 - 0.008H$$

$$k_f = 5/(1 + f'_{ci})$$

$$k_{td} = t/(61 - 4f'_{ci} + t)$$

Where:

- $\psi$  = Creep coefficient.  
 $H$  = 70, Average annual ambient relative humidity  
 $t$  = Maturity of concrete, (days)  
 Use 90 days for camber design.  
 $t_i$  = Age of concrete when a load is initially applied, (days)  
 Use 0.75 days for camber design.  
 $v/s$  = Volume-to-surface area ratio, (in.)  
 $f'_{ci}$  = Initial girder concrete compressive strength, (ksi)

**3.55.3 Details**

**3.1 Reinforcement**

LRFD 5.12.3

**Minimum Concrete Cover**

- 2.0" for strands
- 1.0" for stirrups

LRFD 5.10.2.3

**Minimum Radius of Bar Bend in Stirrups**

#3 through #5 bars = 4.0 x Bar Diameter.

LRFD 5.10.3.1.2

**Minimum Spacing of Reinforcement Bars**

For precast concrete, the clear distance between parallel bars in a layer shall not be lesser than:

- Nominal Diameter of bar
- 1.33 x Maximum Aggregate Size
- 1.0"

LRFD 5.10.3.3

**Minimum Spacing of Prestressing Strands**

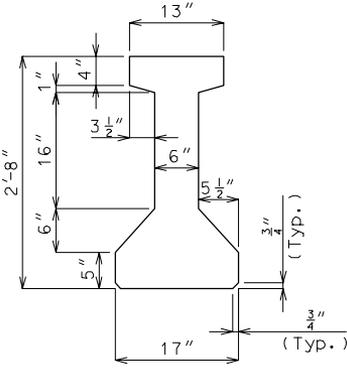
Spacing between each prestressing strand shall not be less than the larger of:

- A clear distance of 1.33 x Maximum Aggregate Size
- Center-to-center spacing of 2" for 0.6" strand diameter
- Center-to-center spacing of 1.75" for 0.5" strand diameter

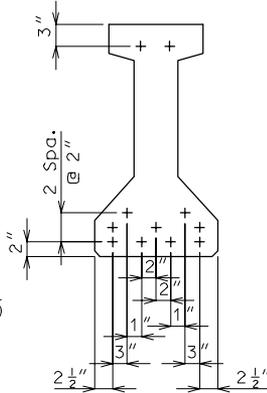
3.2 Beam Type 2

Details

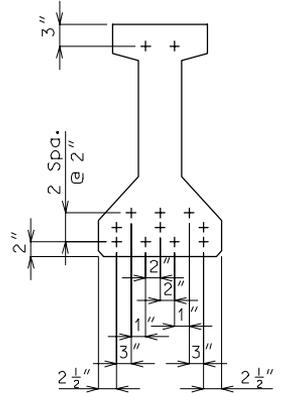
Section Properties and Strand Arrangement



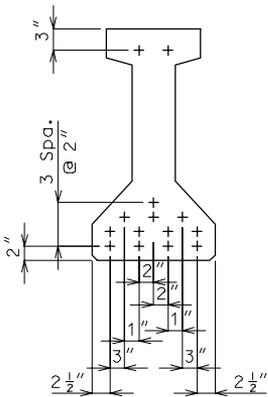
GIRDERS 2A THRU 2C  
 $A = 310.9 \text{ SQ. IN.}$   
 $Y_b = 14.08 \text{ IN.}$   
 $I = 33,974 \text{ IN.}^4$



GIRDER 2A  
(11 STRANDS)



GIRDER 2B  
(12 STRANDS)



GIRDER 2C  
(14 STRANDS)

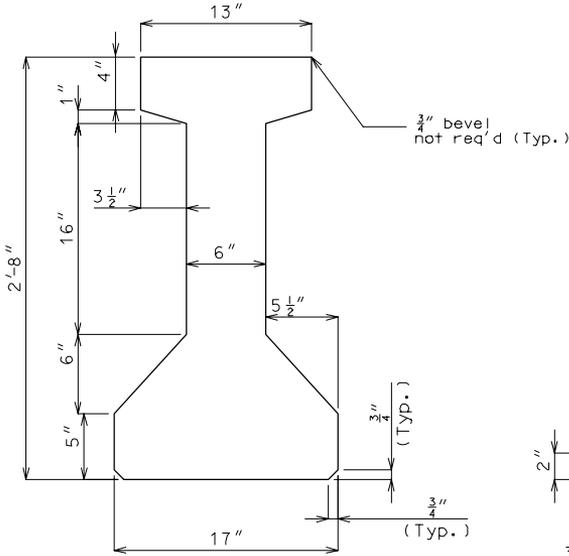
GIRDER SEQ. NO.		2A	2B	2C
Initial Prestress	kips	341	372	434
Size of Strands	in.	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
No. of Strands (All Straight)		11	12	14
Bottom of Girder to Center of Gravity of Strands	inches	8.18	8.00	7.71

NOTE: Investigate the possibility of using all straight strands when strength check of a hold-down device exceeds allowable. All strand arrangements shown on this page have straight strands only.

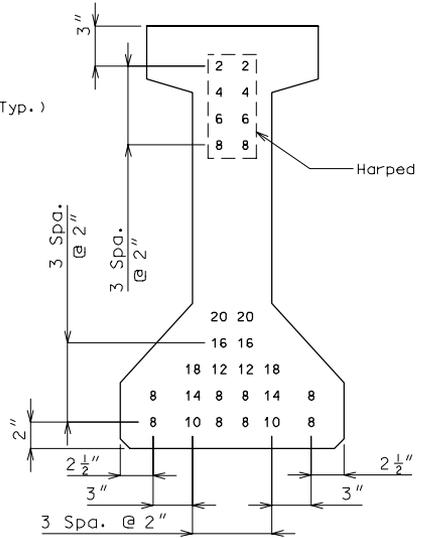
Strand arrangements other than those shown may be investigated by the designer.

Beam Type 2  
Section Properties and Strand Arrangement

Details

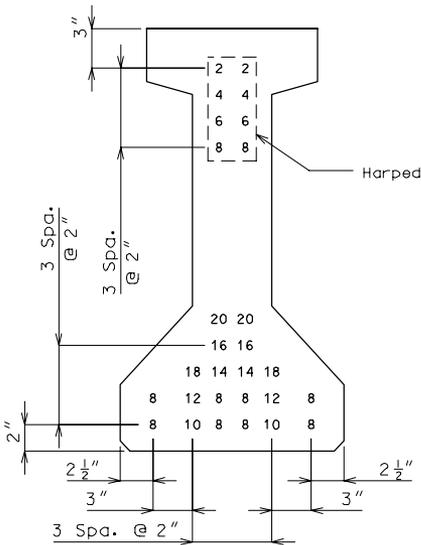


$A = 310.9 \text{ SQ. IN.}$   
 $\gamma_b = 14.08 \text{ IN.}$   
 $I = 33.974 \text{ IN.}^4$



GROUP I

Numbers shown on girders relate to strand locations. See LRFD DG Sec. 3.55.3.7-2 for description of locations.



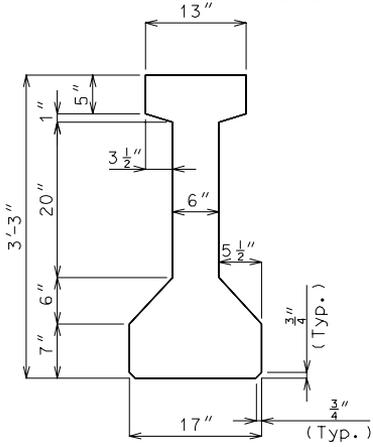
GROUP II

ATTENTION: Location of harped strands shown in top flange are at end of girder and harped strands in bottom flange are at centerline.

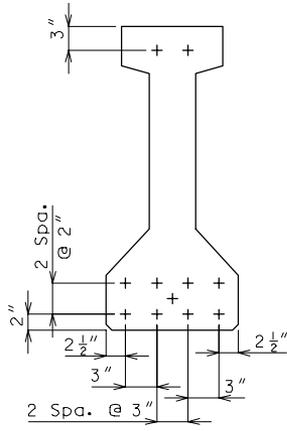
If the web thickness is required to be increased, then the top and bottom flanges are to be increased by the same amount. (1" increments, 2" max.)

3.3 Beam Type 3

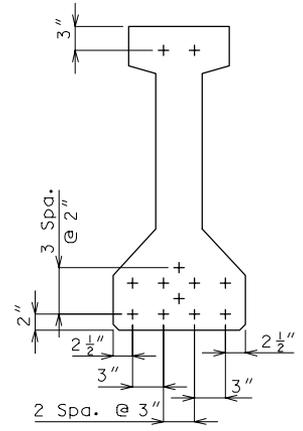
Section Properties and Strand Arrangement (Continuous Spans)



GIRDERS 3A THRU 3C  
 A = 381.9 SQ. IN.  
 $Y_b = 17.08$  IN.  
 $I = 61,841$  IN.<sup>4</sup>



GIRDER 3A  
(11 STRANDS)



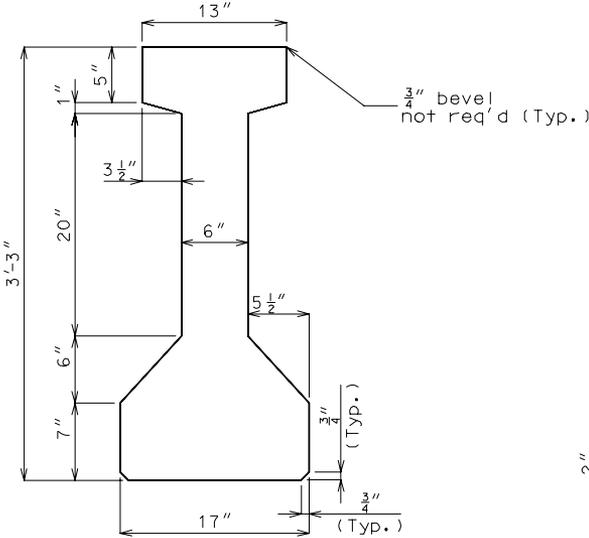
GIRDER 3B  
(12 STRANDS)

GIRDER SEQ. NO.	3A	3B
Initial Prestress	kips 341	372
Size of Strands	in. $\frac{1}{2}$	$\frac{1}{2}$
No. of Strands (All Straight)	11	12
Bottom of Girder to Center of Gravity of Strands	inches 9.82	9.67

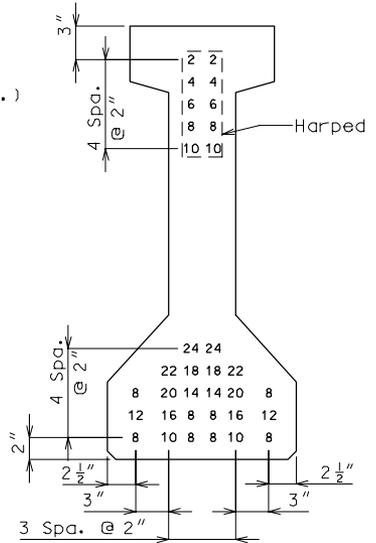
NOTE: Investigate the possibility of using all straight strands when strength check of a hold-down device exceeds allowable. All strand arrangements shown on this page have straight strands only.

Strand arrangements other than those shown may be investigated by the designer.

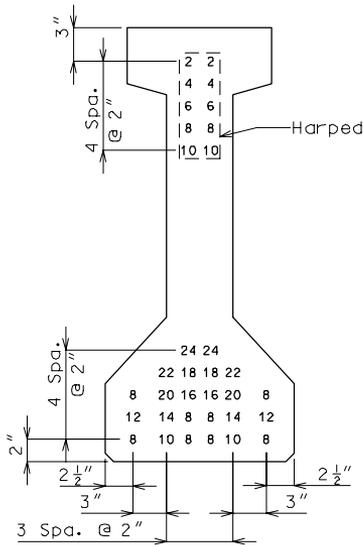
Beam Type 3  
Section Properties and Strand Arrangement



A = 381.9 SQ. IN.  
 $Y_b = 17.08$  IN.  
 I = 61.841 IN.<sup>4</sup>



GROUP I



GROUP II

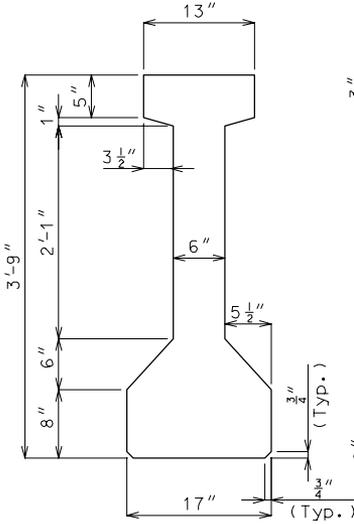
Numbers shown on girders relate to strand locations. See LRFD DG Sec. 3.55.3.7-2 for description of locations.

ATTENTION: Location of harped strands shown in top flange are at end of girder and harped strands in bottom flange are at centerline.

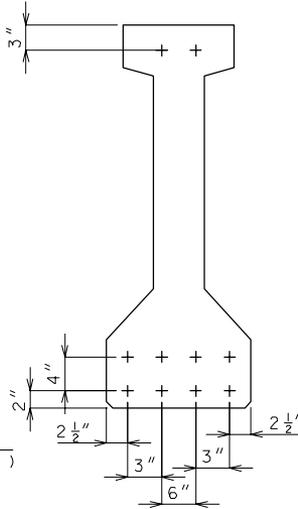
If the web thickness is required to be increased, then the top and bottom flanges are to be increased by the same amount. (1" increments, 2" max.)

3.4 Beam Type 4

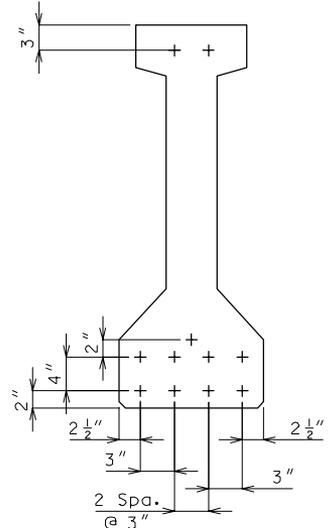
Section Properties and Strand Arrangement (Continuous Spans)



GIRDERS 4A THRU 4C  
 $A = 428.9 \text{ SQ. IN.}$   
 $Y_b = 19.54 \text{ IN.}$   
 $I = 92,450 \text{ IN.}^4$



GIRDER 4A  
(10 STRANDS)

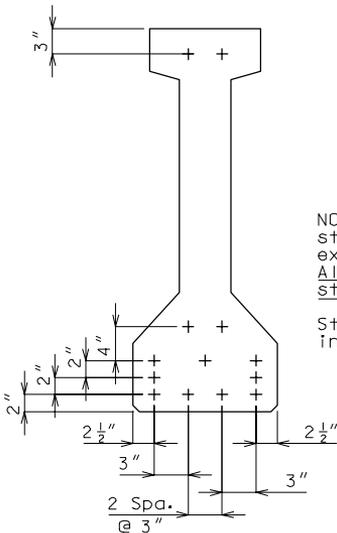


GIRDER 4B  
(11 STRANDS)

GIRDER SEQ. NO.		4A	4B	4C
Initial Prestress	kips	310	341	403
Size of Strands	in.	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
No. of Strands (All Straight)		10	11	12
Bottom of Girder to Center of Gravity of Strands	inches	11.60	11.27	10.62

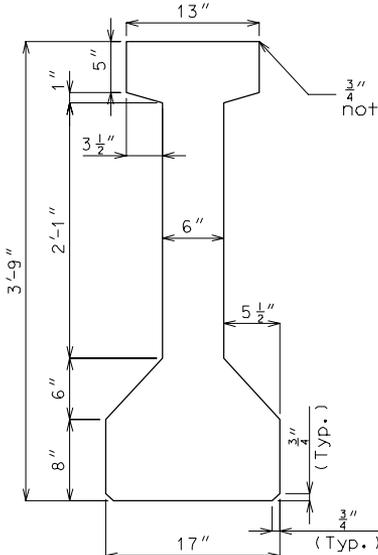
NOTE: Investigate the possibility of using all straight strands when strength check of a hold-down device exceeds allowable.  
All strand arrangements shown on this page have straight strands only.

Strand arrangements other than those shown may be investigated by the designer.

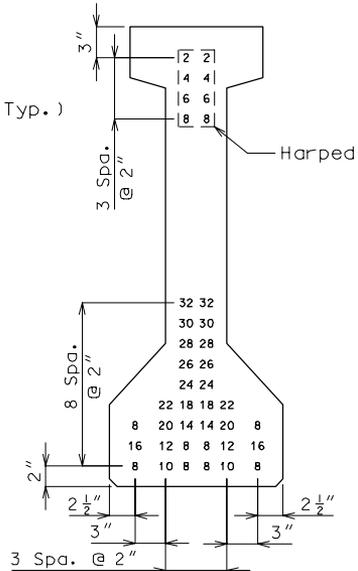


GIRDER 4C  
(13 STRANDS)

Beam Type 4  
Section Properties and Strand Arrangement

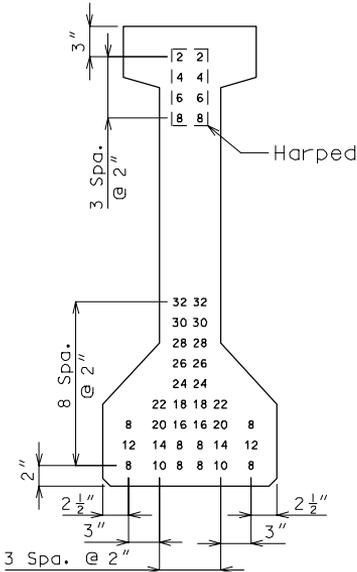


A = 428.9 SQ. IN.  
 $Y_b$  = 19.54 IN.  
 I = 92,450 IN.<sup>4</sup>



GROUP I

Numbers shown on girders relate to strand locations. See LRFD DG Sec. 3.55.3.7-2 for description of locations.



GROUP II

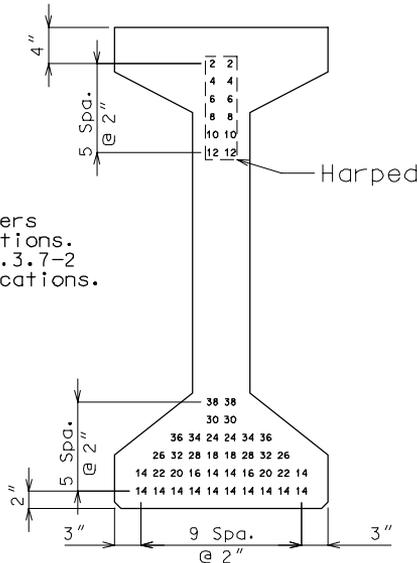
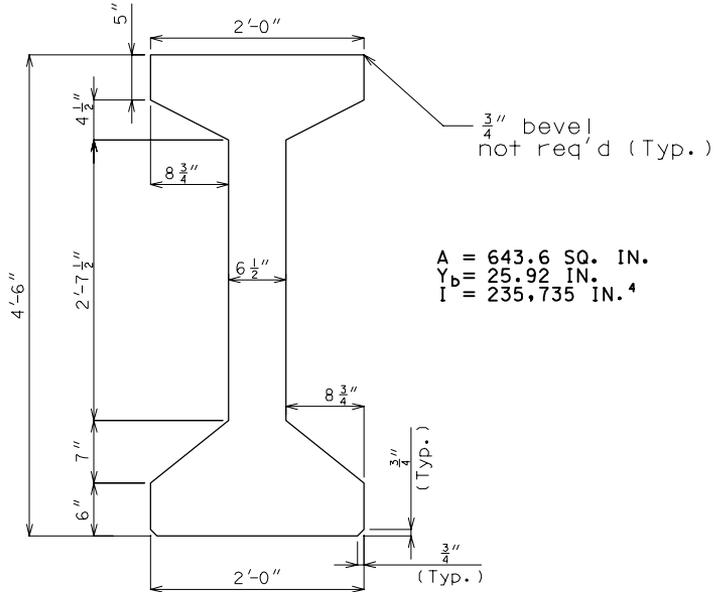
ATTENTION: Location of harped strands shown in top flange are at end of girder and harped strands in bottom flange are at centerline.

If the web thickness is required to be increased, then the top and bottom flanges are to be increased by the same amount. (1" increments, 2" max.)

3.5 Beam Type 6, Group 1

Details

Section Properties and Strand Arrangement



Numbers shown on girders relate to strand locations. See LRFD DG Sec. 3.55.3.7-2 for description of locations.

GROUP I

ATTENTION: Location of harped strands shown in top flange are at end of girder and harped strands in bottom flange are at centerline.

If the web thickness is required to be increased, then the top and bottom flanges are to be increased by the same amount. (1" increments, 2" max.)



### 3.7 Beam Section Properties Tables – Conventional Concrete

The properties of prestressed I-girders in the following tables are valid for  $f'_{ci} = 4.5$  ksi and  $f'_c = 6$  ksi. The modular ratio,  $n$ , is 8 for the initial moment of inertia,  $I_{initial}$ , and 7 for the final moment of inertia,  $I_{final}$ .

Note: Moments of inertia,  $I_{initial}$  and  $I_{final}$  are computed based on transformed non-composite section and are used in camber calculations.

Definitions used in tables are:

Section Area = Gross area of girder, (in.<sup>2</sup>)

Section  $Y_b$  = Distance from bottom of girder to center of gravity of non-transformed non-composite section, (in.)

$I_{nontransformed}$  = Moment of inertia of non-transformed non-composite section, (in.<sup>4</sup>)

Depth = Height of girder, (in.)

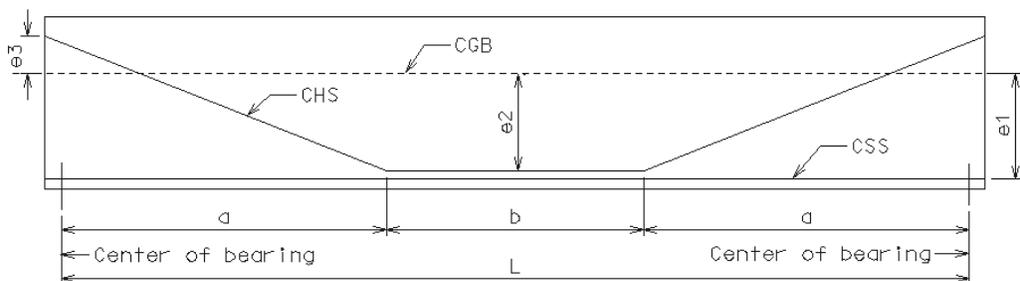
Strand size = Strand diameter, (in.)

$e1^*$  = Eccentricity between centroid of straight strands (CSS) and center of gravity of non-transformed non-composite section (CGB) as shown in figure below, (in.)

$e2^*$  = Eccentricity between centroid of harped strands (CHS) and center of gravity of non-transformed non-composite section (CGB) at midspan as shown in figure below, (in.)

$e3^*$  = Eccentricity between centroid of harped strands (CHS) and center of gravity of non-transformed non-composite section (CGB) at the end of girder as shown in figure below, (in.)

\*A more accurate value can be used based on transformed non-composite section. The final camber calculation will not be significantly different using values between transformed and non-transformed sections.

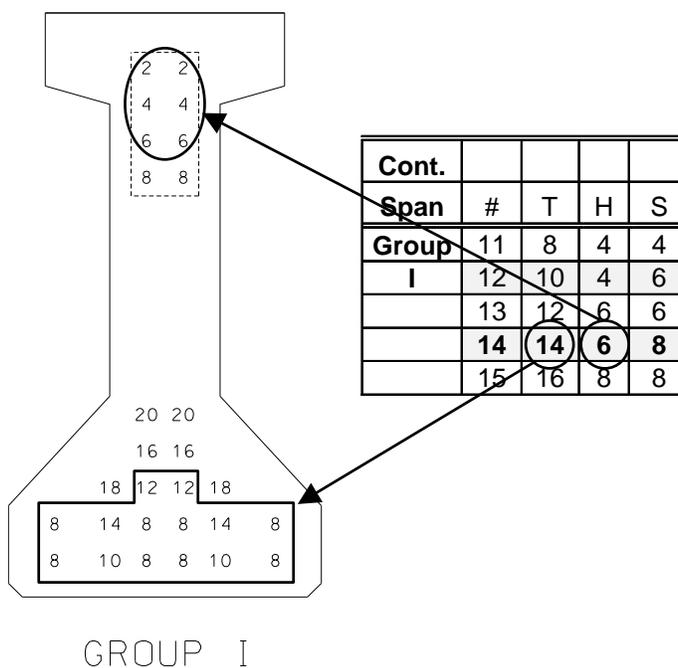


# LRFD Bridge Design Guidelines

*Details*

**Steps for detailing strand patterns from Prestressed Beam Tables**

- 1) For strand locations at mid-span of girder: Look up the “Total Number of Strands” value for the corresponding strand pattern number. The strands will then be located at that number and all numbers below that number. Ex. For 14 total strands, the strands will be placed at all locations numbered  $\leq 14$ .
- 2) For harped strand locations at end of girder: Look up the “Number of Harped Strands” value for the corresponding strand pattern number. The strands will then be located at that number and all numbers below that number. Ex. For 6 harped strands, the strands will be placed at all locations numbered  $\leq 6$ .



## LRFD Bridge Design Guidelines

### Section Properties Beam Type 2 -- 6" Web

Section Area=	310.9	in <sup>2</sup>
Section $Y_b$ =	14.08	in
$I_{nontransformed}$ =	33,974	in <sup>4</sup>
Depth=	32	in
Strand Size=	½	in
$f'_{ci}$ =	4.5	ksi
$f'_c$ =	6	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands  
 See page 3.7-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

	#	T	H	S	e1	e2	e3	$I_{initial}$		$I_{final}$	
								A1 Bars 2-#5	A1 Bars 2-#6	A1 Bars 2-#5	A1 Bars 2-#6
<b>Group I</b>	1	8	4	4	11.08	11.08	13.92	36,147	36,627	35,837	36,248
	2	10	4	6	11.41	11.08	13.92	36,453	36,938	36,100	36,515
	3	12	6	6	11.41	10.08	12.92	36,587	37,075	36,215	36,632
	4	14	6	8	11.08	10.08	12.92	36,794	37,286	36,394	36,814
	5	16	8	8	11.08	9.08	11.92	36,866	37,360	36,456	36,878
	6	18	8	10	10.48	9.08	11.92	36,994	37,491	36,568	36,992
<b>Group II</b>	7	8	2	6	11.41	10.08	14.92	36,147	36,627	35,837	36,248
	8	10	2	8	11.58	10.08	14.92	36,453	36,938	36,100	36,515
	9	12	4	8	11.08	11.08	13.92	36,663	37,151	36,280	36,698
	10	14	4	10	11.28	9.08	13.92	36,794	37,286	36,394	36,814
	11	16	6	10	11.28	8.08	12.92	36,866	37,360	36,456	36,878
	12	18	6	12	10.75	8.08	12.92	36,994	37,491	36,568	36,992
	13	20	6	14	10.65	6.08	12.92	37,024	37,522	36,594	37,019

## LRFD Bridge Design Guidelines

### Section Properties Beam Type 2 -- 7" Web

Section Area=	342.9	in <sup>2</sup>
Section $Y_b$ =	14.26	in
$I_{nontransformed}$ =	36,812	in <sup>4</sup>
Depth=	32	in
Strand Size=	½	in
$f'_{ci}$ =	4.5	ksi
$f'_c$ =	6	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands

See page 3.7-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

	#	T	H	S	e1	e2	e3	$I_{initial}$		$I_{final}$	
								A1 Bars 2-#5	A1 Bars 2-#6	A1 Bars 2-#5	A1 Bars 2-#6
<b>Group I</b>	1	8	4	4	11.26	11.26	13.74	38,994	39,464	38,683	39,085
	2	10	4	6	11.59	11.26	13.74	39,310	39,784	38,954	39,360
	3	12	6	6	11.59	10.26	12.74	39,450	39,927	39,075	39,482
	4	14	6	8	11.26	10.26	12.74	39,666	40,146	39,261	39,671
	5	16	8	8	11.26	9.26	11.74	39,742	40,225	39,327	39,739
	6	18	8	10	10.66	9.26	11.74	39,877	40,363	39,444	39,858
<b>Group II</b>	7	8	2	6	11.59	10.26	14.74	38,994	39,464	38,683	39,085
	8	10	2	8	11.76	10.26	14.74	39,310	39,784	38,954	39,360
	9	12	4	8	11.26	11.26	13.74	39,528	40,005	39,142	39,550
	10	14	4	10	11.46	9.26	13.74	39,666	40,146	39,261	39,671
	11	16	6	10	11.46	8.26	12.74	39,742	40,225	39,327	39,739
	12	18	6	12	10.93	8.26	12.74	39,877	40,363	39,444	39,858
	13	20	6	14	10.83	6.26	12.74	39,910	39,473	39,473	39,888

# LRFD Bridge Design Guidelines

## Section Properties Beam Type 2 -- 8" Web

Section Area=	374.9	in <sup>2</sup>
Section $Y_b$ =	14.41	in
$I_{nontransformed}$ =	39,632	in <sup>4</sup>
Depth=	32	in
Strand Size=	½	in
$f'_{ci}$ =	4.5	ksi
$f'_c$ =	6	ksi

NOTE: # = strand pattern number

T = total number of strands

H = number of harped strands

S = number of straight strands

See page 3.7-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

	#	T	H	S	e1	e2	e3	$I_{initial}$		$I_{final}$	
								A1 Bars	A1 Bars	A1 Bars	A1 Bars
								2-#5	2-#6	2-#5	2-#6
<b>Group I</b>	1	8	4	4	11.41	11.41	13.59	41,823	42,283	41,510	41,905
	2	10	4	6	11.74	11.41	13.59	42,147	42,611	41,789	42,186
	3	12	6	6	11.74	10.41	12.59	42,292	42,760	41,914	42,313
	4	14	6	8	11.41	10.41	12.59	42,515	42,985	42,106	42,508
	5	16	8	8	11.41	9.41	11.59	42,596	43,068	42,176	42,579
	6	18	8	10	10.81	9.41	11.59	42,737	43,212	42,298	42,703
<b>Group II</b>	7	8	2	6	11.74	10.41	14.59	41,823	42,283	41,510	41,905
	8	10	2	8	11.91	10.41	14.59	42,147	42,611	41,789	42,186
	9	12	4	8	11.41	11.41	13.59	42,371	42,839	41,982	42,382
	10	14	4	10	11.61	9.41	13.59	42,515	42,985	42,106	42,508
	11	16	6	10	11.61	8.41	12.59	42,596	43,068	42,176	42,579
	12	18	6	12	11.08	8.41	12.59	42,737	43,212	42,298	42,703
	13	20	6	14	10.98	6.41	12.59	42,772	43,249	42,329	42,736

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 3 -- 6" Web

Section Area=	381.9	in <sup>2</sup>
Section Y <sub>b</sub> =	17.08	in
I <sub>nontransformed</sub> =	61,841	in <sup>4</sup>
Depth=	39	in
Strand Size=	½	in
f' <sub>ci</sub> =	4.5	ksi
f' <sub>c</sub> =	6	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands  
 See page 3.7-1 for definitions of e1, e2, e3, I<sub>initial</sub>, and I<sub>final</sub>.

Cont.	Span	#	T	H	S	e1	e2	e3	I <sub>initial</sub>		I <sub>final</sub>	
									A1 Bars 2-#5	A1 Bars 2-#6	A1 Bars 2-#5	A1 Bars 2-#6
<b>Group I</b>	1	8	4	4	13.08	14.08	17.92	65,179	65,930	64,702	65,346	
	2	10	4	6	13.75	14.08	17.92	65,659	66,415	65,114	65,762	
	3	12	4	8	13.58	14.08	17.92	66,014	66,776	65,421	66,072	
	4	14	6	8	13.58	13.08	16.92	66,265	67,032	65,637	66,292	
	5	16	6	10	13.48	13.08	16.92	66,614	67,386	65,938	66,597	
	6	18	8	10	13.48	12.08	15.92	66,776	67,552	66,079	66,740	
	7	20	8	12	13.08	12.08	15.92	67,020	67,799	66,290	66,954	
	8	22	8	14	12.51	12.08	15.92	67,178	67,961	66,427	67,095	
	9	24	10	14	12.51	11.08	14.92	67,270	68,056	66,508	67,177	
<b>Group II</b>	10	8	2	6	13.75	13.08	18.92	65,179	65,930	64,702	65,346	
	11	10	2	8	14.08	13.08	18.92	65,659	66,415	65,114	65,762	
	12	12	2	10	13.88	13.08	18.92	66,014	66,776	65,421	66,072	
	13	14	4	10	13.48	14.08	17.92	66,366	67,134	65,724	66,379	
	14	16	4	12	13.75	12.08	17.92	66,614	67,386	65,938	66,597	
	15	18	6	12	13.75	11.08	16.92	66,776	67,552	66,079	66,740	
	16	20	6	14	13.37	11.08	16.92	67,020	67,799	66,290	66,954	
	17	22	6	16	12.83	11.08	16.92	67,178	67,961	66,427	67,095	
	18	24	8	16	12.83	10.08	15.92	67,270	68,056	66,508	67,177	

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 3 -- 7" Web

Section Area=	420.9	in <sup>2</sup>
Section Y <sub>b</sub> =	17.31	in
I <sub>nontransformed</sub> =	66,991	in <sup>4</sup>
Depth=	39	in
Strand Size=	½	in
f' <sub>ci</sub> =	4.5	ksi
f' <sub>c</sub> =	6	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands  
 See page 3.7-1 for definitions of e1, e2, e3, I<sub>initial</sub>, and I<sub>final</sub>.

Cont.	Span	#	T	H	S	e1	e2	e3	I <sub>initial</sub>		I <sub>final</sub>	
									A1 Bars 2-#5	A1 Bars 2-#6	A1 Bars 2-#5	A1 Bars 2-#6
<b>Group I</b>	1	8	4	4	13.31	14.31	17.69	70,343	71,077	69,865	70,493	
	2	10	4	6	13.98	14.31	17.69	70,838	71,577	70,289	70,922	
	3	12	4	8	13.81	14.31	17.69	71,207	71,951	70,607	71,243	
	4	14	6	8	13.81	13.31	16.69	71,469	72,218	70,833	71,473	
	5	16	6	10	13.71	13.31	16.69	71,832	72,585	71,146	71,789	
	6	18	8	10	13.71	12.31	15.69	72,004	72,760	71,295	71,940	
	7	20	8	12	13.31	12.31	15.69	72,259	73,019	71,516	72,164	
	8	22	8	14	12.74	12.31	15.69	72,427	73,190	71,662	72,312	
	9	24	10	14	12.74	11.31	14.69	72,526	73,292	71,749	72,401	
<b>Group II</b>	10	8	2	6	13.98	13.31	18.69	70,343	71,077	69,865	70,493	
	11	10	2	8	14.31	13.31	18.69	70,838	71,577	70,289	70,922	
	12	12	2	10	14.11	13.31	18.69	71,207	71,951	70,607	71,243	
	13	14	4	10	13.71	14.31	17.69	71,572	72,322	70,922	71,562	
	14	16	4	12	13.98	12.31	17.69	71,832	72,585	71,146	71,789	
	15	18	6	12	13.98	11.31	16.69	72,004	72,760	71,295	71,940	
	16	20	6	14	13.60	11.31	16.69	72,259	73,019	71,516	72,164	
	17	22	6	16	13.06	11.31	16.69	72,427	73,190	71,662	72,312	
	18	24	8	16	13.06	10.31	15.69	72,526	73,292	71,749	72,401	

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 3 -- 8" Web

Section Area=	459.9	in <sup>2</sup>
Section Y <sub>b</sub> =	17.49	in
I <sub>nontransformed</sub> =	72,106	in <sup>4</sup>
Depth=	39	in
Strand Size=	½	in
f'ci =	4.5	ksi
f'c =	6	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands  
 See page 3.7-1 for definitions of e1, e2, e3, I<sub>initial</sub>, and I<sub>final</sub>.

Cont.	Span	#	T	H	S	e1	e2	e3	I <sub>initial</sub>		I <sub>final</sub>	
									A1 Bars 2-#5	A1 Bars 2-#6	A1 Bars 2-#5	A1 Bars 2-#6
<b>Group I</b>	1	8	4	4	13.49	14.49	17.51	75,470	76,191	74,990	75,607	
	2	10	4	6	14.16	14.49	17.51	75,977	76,703	75,425	76,046	
	3	12	4	8	13.99	14.49	17.51	76,357	77,087	75,752	76,376	
	4	14	6	8	13.99	13.49	16.51	76,628	77,363	75,986	76,613	
	5	16	6	10	13.89	13.49	16.51	77,002	77,740	76,308	76,939	
	6	18	8	10	13.89	12.49	15.51	77,182	77,923	76,464	77,096	
	7	20	8	12	13.49	12.49	15.51	77,446	78,191	76,692	77,328	
	8	22	8	14	12.92	12.49	15.51	77,622	78,370	76,845	77,483	
	9	24	10	14	12.92	11.49	14.51	77,728	78,479	76,938	77,577	
<b>Group II</b>	10	8	2	6	14.16	13.49	18.51	75,470	76,191	74,990	75,607	
	11	10	2	8	14.49	13.49	18.51	75,977	76,703	75,425	76,046	
	12	12	2	10	14.29	13.49	18.51	76,357	77,087	75,752	76,376	
	13	14	4	10	13.89	14.49	17.51	76,733	77,468	76,076	76,704	
	14	16	4	12	14.16	12.49	17.51	77,002	77,740	76,308	76,939	
	15	18	6	12	14.16	11.49	16.51	77,182	77,923	76,464	77,096	
	16	20	6	14	13.78	11.49	16.51	77,446	78,191	76,692	77,328	
	17	22	6	16	13.24	11.49	16.51	77,622	78,370	76,845	77,483	
	18	24	8	16	13.24	10.49	15.51	77,728	78,479	76,938	77,577	

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 4 -- 6" Web

Section Area=	428.9	in <sup>2</sup>
Section $Y_b$ =	19.54	in
$I_{nontransformed}$ =	92,450	in <sup>4</sup>
Depth=	45	in
Strand Size=	½	in
$f'_{ci}$ =	4.5	ksi
$f'_c$ =	6	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands

See page 3.7-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

Cont.								$I_{initial}$		$I_{final}$	
	Span	#	T	H	S	e1	e2	e3	A1 Bars 2-#5	A1 Bars 2-#6	A1 Bars 2-#5
<b>Group I</b>	1	8	4	4	15.54	16.54	21.46	97,077	98,118	96,416	97,308
	2	10	4	6	16.21	16.54	21.46	97,727	98,775	96,974	97,872
	3	12	4	8	16.04	16.54	21.46	98,231	99,286	97,408	98,310
	4	14	6	8	16.04	15.54	20.46	98,608	99,669	97,733	98,640
	5	16	6	10	15.94	15.54	20.46	99,103	100,170	98,160	99,071
	6	18	8	10	15.94	14.54	19.46	99,368	100,441	98,390	99,305
	7	20	8	12	15.54	14.54	19.46	99,735	100,813	98,707	99,626
	8	22	8	14	14.97	14.54	19.46	99,995	101,078	98,933	99,856
	9	24	8	16	15.29	12.54	19.46	100,168	101,254	99,083	100,009
	10	26	10	16	15.29	11.54	18.46	100,271	101,360	99,174	100,102
	11	28	10	18	15.32	9.54	18.46	100,323	101,414	99,220	100,149
<b>Group II</b>	12	8	2	6	16.21	15.54	22.46	97,077	98,118	96,416	97,308
	13	10	2	8	16.54	15.54	22.46	97,727	98,775	96,974	97,872
	14	12	4	8	16.04	16.54	21.46	98,231	99,286	97,408	98,310
	15	14	4	10	15.94	16.54	21.46	98,730	99,792	97,838	98,745
	16	16	4	12	16.21	14.54	21.46	99,103	100,170	98,160	99,071
	17	16	6	10	15.94	15.54	20.46	99,103	100,170	98,160	99,071
	18	18	6	12	16.21	13.54	20.46	99,368	100,441	98,390	99,305
	19	20	6	14	15.83	13.54	20.46	99,735	100,813	98,707	99,626
	20	22	6	16	15.29	13.54	20.46	99,995	101,078	98,933	99,856
	21	24	6	18	15.32	11.54	20.46	100,168	101,254	99,083	100,009
	22	26	6	20	15.14	9.54	20.46	100,271	101,360	99,174	100,102
	23	26	8	18	15.32	10.54	19.46	100,271	101,360	99,174	100,102
	24	28	6	22	14.81	7.54	20.46	100,323	101,414	99,220	100,149
	25	28	8	20	15.14	8.54	19.46	100,323	101,414	99,220	100,149
	26	30	8	22	14.81	6.54	19.46	100,341	101,433	99,236	100,166
	27	32	8	24	14.37	4.54	19.46	100,342	101,435	99,238	100,168

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 4 -- 7" Web

Section Area=	473.9	in <sup>2</sup>
Section Y <sub>b</sub> =	19.82	in
I <sub>nontransformed</sub> =	100,400	in <sup>4</sup>
Depth=	45	in
Strand Size=	½	in
f' <sub>ci</sub> =	4.5	ksi
f' <sub>c</sub> =	6	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands

See page 3.7-1 for definitions of e1, e2, e3, I<sub>initial</sub>, and I<sub>final</sub>.

Cont.	Span	#	T	H	S	e1	e2	e3	I <sub>initial</sub>		I <sub>final</sub>	
									A1 Bars 2-#5	A1 Bars 2-#6	A1 Bars 2-#5	A1 Bars 2-#6
<b>Group I</b>	1	8	4	4	15.82	16.82	21.18	105,048	106,065	104,384	105,256	
	2	10	4	6	16.49	16.82	21.18	105,719	106,743	104,960	105,837	
	3	12	4	8	16.32	16.82	21.18	106,242	107,272	105,410	106,291	
	4	14	6	8	16.32	15.82	20.18	106,636	107,671	105,750	106,635	
	5	16	6	10	16.22	15.82	20.18	107,151	108,192	106,193	107,083	
	6	18	8	10	16.22	14.82	19.18	107,431	108,476	106,436	107,328	
	7	20	8	12	15.82	14.82	19.18	107,815	108,866	106,768	107,664	
	8	22	8	14	15.25	14.82	19.18	108,090	109,145	107,007	107,906	
	9	24	8	16	15.57	12.82	19.18	108,275	109,334	107,168	108,070	
	10	26	10	16	15.57	11.82	18.18	108,388	109,449	107,266	108,171	
	11	28	10	18	15.60	9.82	18.18	108,446	109,510	107,318	108,224	
<b>Group II</b>	12	8	2	6	16.49	15.82	22.18	105,048	106,065	104,384	105,256	
	13	10	2	8	16.82	15.82	22.18	105,719	106,743	104,960	105,837	
	14	12	4	8	16.32	16.82	21.18	106,242	107,272	105,410	106,291	
	15	14	4	10	16.22	16.82	21.18	106,760	107,796	105,857	106,742	
	16	16	4	12	16.49	14.82	21.18	107,151	108,192	106,193	107,083	
	17	16	6	10	16.22	15.82	20.18	107,151	108,192	106,193	107,083	
	18	18	6	12	16.49	13.82	20.18	107,431	108,476	106,436	107,328	
	19	20	6	14	16.11	13.82	20.18	107,815	108,866	106,768	107,664	
	20	22	6	16	15.57	13.82	20.18	108,090	109,145	107,007	107,906	
	21	24	6	18	15.60	11.82	20.18	108,275	109,334	107,168	108,070	
	22	26	6	20	15.42	9.82	20.18	108,388	109,449	107,266	108,171	
	23	26	8	18	15.60	10.82	19.18	108,388	109,449	107,266	108,171	
	24	28	6	22	15.09	7.82	20.18	108,446	109,510	107,318	108,224	
	25	28	8	20	15.42	8.82	19.18	108,446	109,510	107,318	108,224	
	26	30	8	22	15.09	6.82	19.18	108,469	109,533	107,338	108,245	
	27	32	8	24	14.65	4.82	19.18	108,472	109,537	107,341	108,248	

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 4 -- 8" Web

Section Area=	518.9	in <sup>2</sup>
Section $Y_b$ =	20.06	in
$I_{nontransformed}$ =	108,288	in <sup>4</sup>
Depth=	45	in
Strand Size=	½	in
$f'_{ci}$ =	4.5	ksi
$f'_c$ =	6	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands

See page 3.7-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

Cont.	Span	#	T	H	S	e1	e2	e3	$I_{initial}$		$I_{final}$	
									A1 Bars 2-#5	A1 Bars 2-#6	A1 Bars 2-#5	A1 Bars 2-#6
<b>Group I</b>	1	8	4	4	16.06	17.06	20.94	112,955	113,952	112,289	113,143	
	2	10	4	6	16.73	17.06	20.94	113,645	114,648	112,881	113,739	
	3	12	4	8	16.56	17.06	20.94	114,185	115,193	113,345	114,208	
	4	14	6	8	16.56	16.06	19.94	114,594	115,607	113,698	114,563	
	5	16	6	10	16.46	16.06	19.94	115,126	116,144	114,156	115,026	
	6	18	8	10	16.46	15.06	18.94	115,419	116,442	114,409	115,282	
	7	20	8	12	16.06	15.06	18.94	115,818	116,846	114,755	115,631	
	8	22	8	14	15.49	15.06	18.94	116,107	117,138	115,004	115,884	
	9	24	8	16	15.81	13.06	18.94	116,303	117,337	115,175	116,057	
	10	26	10	16	15.81	12.06	17.94	116,424	117,461	115,281	116,165	
	11	28	10	18	15.84	10.06	17.94	116,489	117,528	115,338	116,223	
<b>Group II</b>	12	8	2	6	16.73	16.06	21.94	112,955	113,952	112,289	113,143	
	13	10	2	8	17.06	16.06	21.94	113,645	114,648	112,881	113,739	
	14	12	4	8	16.56	17.06	20.94	114,185	115,193	113,345	114,208	
	15	14	4	10	16.46	17.06	20.94	114,720	115,734	113,806	114,673	
	16	16	4	12	16.73	15.06	20.94	115,126	116,144	114,156	115,026	
	17	16	6	10	16.46	16.06	19.94	115,126	116,144	114,156	115,026	
	18	18	6	12	16.73	14.06	19.94	115,419	116,442	114,409	115,282	
	19	20	6	14	16.35	14.06	19.94	115,818	116,846	114,755	115,631	
	20	22	6	16	15.81	14.06	19.94	116,107	117,138	115,004	115,884	
	21	24	6	18	15.84	12.06	19.94	116,303	117,337	115,175	116,057	
	22	26	6	20	15.66	10.06	19.94	116,424	117,461	115,281	116,165	
	23	26	8	18	15.84	11.06	18.94	116,424	117,461	115,281	116,165	
	24	28	6	22	15.33	8.06	19.94	116,489	117,528	115,338	116,223	
	25	28	8	20	15.66	9.06	18.94	116,489	117,528	115,338	116,223	
	26	30	8	22	15.33	7.06	18.94	116,515	117,555	115,361	116,247	
	27	32	8	24	14.89	5.06	18.94	116,520	117,560	115,366	116,252	

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 6 -- 6.5" Web

Section Area=	643.6	in <sup>2</sup>
Section $Y_b$ =	25.92	in
$I_{nontransformed}$ =	235,735	in <sup>4</sup>
Depth=	54	in
Strand Size=	½	in
$f'_{ci}$ =	4.5	ksi
$f'_c$ =	6	ksi

NOTE: # = strand pattern number

T = total number of strands

H = number of harped strands

S = number of straight strands

See page 3.7-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

								$I_{initial}$	$I_{final}$
	#	T	H	S	e1	e2	e3	A1 Bars 2-#6	A1 Bars 2-#6
<b>Group</b>	1	14	4	10	23.52	22.92	23.08	249,649	247,665
<b>I</b>	2	16	4	12	23.25	22.92	23.08	250,657	248,531
	3	18	6	12	23.25	21.92	22.08	251,482	249,241
	4	20	6	14	23.06	21.92	22.08	252,478	250,098
	5	22	6	16	22.92	21.92	22.08	253,467	250,951
	6	24	8	16	22.92	20.92	21.08	254,117	251,513
	7	26	8	18	22.59	20.92	21.08	254,921	252,207
	8	28	8	20	22.32	20.92	21.08	255,720	252,897
	9	30	10	20	22.32	19.92	20.08	256,218	253,330
	10	32	10	22	22.10	19.92	20.08	257,008	254,014
	11	34	10	24	21.75	19.92	20.08	257,638	254,560
	12	36	10	26	21.46	19.92	20.08	258,263	255,103
	13	38	12	26	21.46	18.92	19.08	258,628	255,421

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 6 -- 7.5" Web

Section Area=	697.6	in <sup>2</sup>
Section $Y_b$ =	26.00	in
$I_{nontransformed}$ =	248,915	in <sup>4</sup>
Depth=	54	in
Strand Size=	½	in
$f'_{ci}$ =	4.5	ksi
$f'_c$ =	6	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands

See page 3.7-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

								$I_{initial}$	$I_{final}$
	#	T	H	S	e1	e2	e3	A1 Bars 2-#6	A1 Bars 2-#6
<b>Group</b>	1	14	4	10	23.60	23.00	23.00	262,852	260,864
<b>I</b>	2	16	4	12	23.33	23.00	23.00	263,868	261,737
	3	18	6	12	23.33	22.00	22.00	264,701	262,454
	4	20	6	14	23.14	22.00	22.00	265,707	263,319
	5	22	6	16	23.00	22.00	22.00	266,706	264,180
	6	24	8	16	23.00	21.00	21.00	267,365	264,749
	7	26	8	18	22.67	21.00	21.00	268,178	265,452
	8	28	8	20	22.40	21.00	21.00	268,987	266,150
	9	30	10	20	22.40	20.00	20.00	269,493	266,589
	10	32	10	22	22.18	20.00	20.00	270,294	267,282
	11	34	10	24	21.83	20.00	20.00	270,933	267,836
	12	36	10	26	21.54	20.00	20.00	271,569	268,387
	13	38	12	26	21.54	19.00	19.00	271,941	268,712

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 6 -- 8.5" Web

Section Area=	751.6	in <sup>2</sup>
Section $Y_b$ =	26.07	in
$I_{nontransformed}$ =	262,087	in <sup>4</sup>
Depth=	54	in
Strand Size=	½	in
$f'_{ci}$ =	4.5	ksi
$f'_c$ =	6	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands

See page 3.7-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

	#	T	H	S	e1	e2	e3	$I_{initial}$ A1 Bars 2-#6	$I_{final}$ A1 Bars 2-#6
<b>Group</b>	1	14	4	10	23.67	23.07	22.93	276,043	274,052
<b>I</b>	2	16	4	12	23.40	23.07	22.93	277,068	274,932
	3	18	6	12	23.40	22.07	21.93	277,908	275,656
	4	20	6	14	23.21	22.07	21.93	278,922	276,528
	5	22	6	16	23.07	22.07	21.93	279,930	277,396
	6	24	8	16	23.07	21.07	20.93	280,596	277,971
	7	26	8	18	22.74	21.07	20.93	281,418	278,680
	8	28	8	20	22.47	21.07	20.93	282,236	279,386
	9	30	10	20	22.47	20.07	19.93	282,750	279,831
	10	32	10	22	22.25	20.07	19.93	283,559	280,531
	11	34	10	24	21.90	20.07	19.93	284,207	281,093
	12	36	10	26	21.61	20.07	19.93	284,851	281,651
	13	38	12	26	21.61	19.07	18.93	285,230	281,981

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 7 -- 6" Web

#### Bulb Tee Girder

Section Area=	787.4	in <sup>2</sup>
Section $Y_b$ =	37.58	in
$I_{nontransformed}$ =	571,047	in <sup>4</sup>
Depth=	72.5	in
Strand Size=	½	in
$f'_{ci}$ =	4.5	ksi
$f'_c$ =	6	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands

See page 3.7-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

Cont.								$I_{initial}$	$I_{final}$
Span	#	T	H	S	e1	e2	e3	A1 Bars 4-#6	A1 Bars 4-#6
<b>Group</b>	1	14	4	10	35.58	34.58	29.92	603,636	598,983
<b>I</b>	2	16	4	12	35.25	34.58	29.92	606,025	601,033
	3	18	6	12	35.25	33.58	28.92	608,125	602,838
	4	20	6	14	35.01	33.58	28.92	610,490	604,871
	5	22	6	16	34.83	33.58	28.92	612,843	606,895
	6	24	8	16	34.83	32.58	27.92	614,652	608,453
	7	26	8	18	34.69	32.58	27.92	616,981	610,459
	8	28	8	20	34.58	32.58	27.92	619,299	612,457
	9	30	10	20	34.58	31.58	26.92	620,839	613,788
	10	32	10	22	34.31	31.58	26.92	622,864	615,536
	11	34	10	24	34.08	31.58	26.92	624,878	617,276
	12	36	10	26	33.89	31.58	26.92	626,881	619,009
	13	38	10	28	33.58	31.58	26.92	628,622	620,517
	14	40	12	28	33.58	30.58	25.92	629,902	621,627

**Details**

### 3.8 Beam Section Properties Tables – Higher strength concrete

The properties of prestressed I-girders in the following tables are valid for  $f'_{ci} = 5$  ksi and  $f'_c = 7$  ksi. The modular ratio,  $n$ , used for both prestressing strands and A1 Bars is 7 for the initial moment of inertia,  $I_{initial}$ , and 6 for the final moment of inertia,  $I_{final}$ .

Note: Moments of inertia,  $I_{initial}$  and  $I_{final}$  are computed based on transformed non-composite section and are used in camber calculations. A1 Bar locations are assumed at 3" from the top of girder.

Definitions used in tables are:

Section Area = Gross area of girder, (in.<sup>2</sup>)

Section  $Y_b$  = Distance from bottom of girder to center of gravity of non-transformed non-composite section, (in.)

$I_{nontransformed}$  = Moment of inertia of non-transformed non-composite section, (in.<sup>4</sup>)

Depth = Height of girder, (in.)

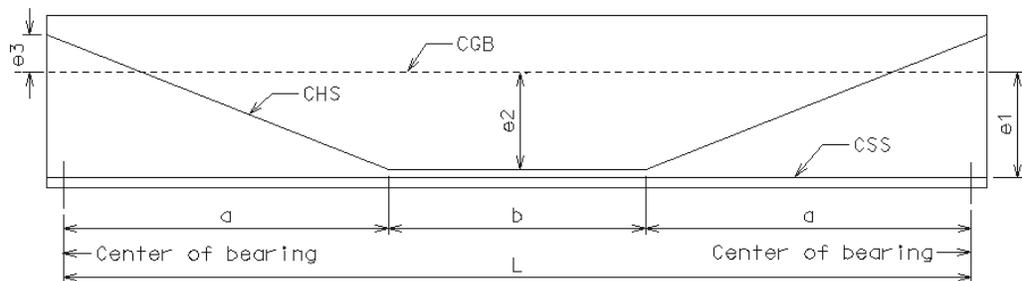
Strand size = Strand diameter, (in.)

$e1^*$  = Eccentricity between centroid of straight strands (CSS) and center of gravity of non-transformed non-composite section (CGB) as shown in figure below, (in.)

$e2^*$  = Eccentricity between centroid of harped strands (CHS) and center of gravity of non-transformed non-composite section (CGB) at midspan as shown in figure below, (in.)

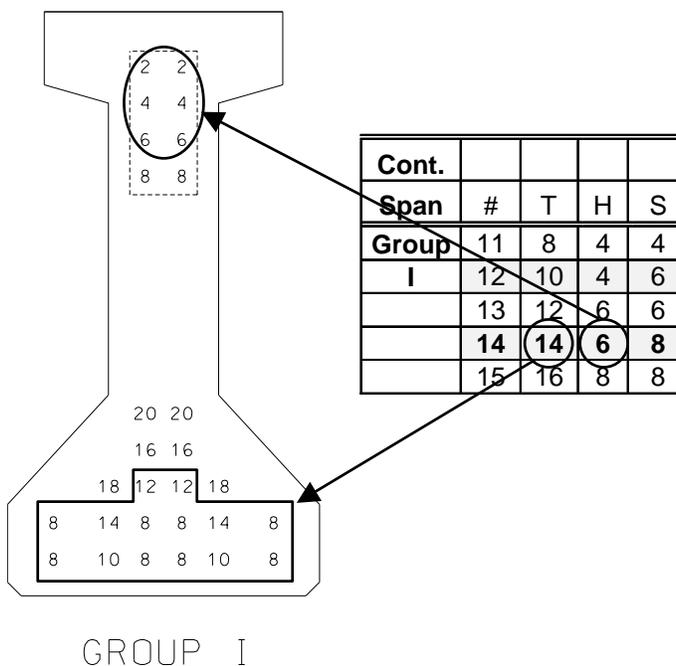
$e3^*$  = Eccentricity between centroid of harped strands (CHS) and center of gravity of non-transformed non-composite section (CGB) at the end of girder as shown in figure below, (in.)

\*A more accurate value can be used based on transformed non-composite section. The final camber calculation will not be significantly different using values between transformed and non-transformed sections.



#### **Steps for detailing strand patterns from Prestressed Beam Tables**

- 1) For strand locations at mid-span of girder: Look up the “Total Number of Strands” value for the corresponding strand pattern number. The strands will then be located at that number and all numbers below that number. Ex. For 14 total strands, the strands will be placed at all locations numbered  $\leq 14$ .
- 2) For harped strand locations at end of girder: Look up the “Number of Harped Strands” value for the corresponding strand pattern number. The strands will then be located at that number and all numbers below that number. Ex. For 6 harped strands, the strands will be placed at all locations numbered  $\leq 6$ .



# LRFD Bridge Design Guidelines

## Section Properties Beam Type 2 -- 6" Web

Section Area=	310.9	in <sup>2</sup>
Section $Y_b$ =	14.08	in
$I_{nontransformed}$ =	33,974	in <sup>4</sup>
Depth=	32	in
Strand Size=	0.6	in
$f'_{ci}$ =	5	ksi
$f'_c$ =	7	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands  
 See page 3.8-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

	#	T	H	S	e1	e2	e3	$I_{initial}$		$I_{final}$	
								A1 Bars 2-#5	A1 Bars 2-#6	A1 Bars 2-#5	A1 Bars 2-#6
<b>Group I</b>	1	8	4	4	11.08	11.08	13.92	36407	36838	36062	36429
	2	10	4	6	11.41	11.08	13.92	36828	37265	36424	36797
	3	12	6	6	11.41	10.08	12.92	36983	37424	36559	36935
	4	14	6	8	11.08	10.08	12.92	37265	37711	36804	37183
	5	16	8	8	11.08	9.08	11.92	37304	37753	36839	37221
	6	18	8	10	10.48	9.08	11.92	37465	37917	36980	37364
<b>Group II</b>	7	8	2	6	11.41	10.08	14.92	36407	36837	36061	36429
	8	10	2	8	11.58	10.08	14.92	36829	37265	36425	36797
	9	12	4	8	11.08	11.08	13.92	37112	37553	36670	37046
	10	14	4	10	11.28	9.08	13.92	37265	37711	36804	37183
	11	16	6	10	11.28	8.08	12.92	37304	37753	36839	37221
	12	18	6	12	10.75	8.08	12.92	37466	37918	36981	37365
	13	20	6	14	10.65	6.08	12.92	37409	37864	36934	37320

## LRFD Bridge Design Guidelines

### Section Properties Beam Type 2 -- 7" Web

Section Area=	342.9	in <sup>2</sup>
Section $Y_b$ =	14.26	in
$I_{nontransformed}$ =	36,812	in <sup>4</sup>
Depth=	32	in
Strand Size=	0.6	in
$f'_{ci}$ =	5	ksi
$f'_c$ =	7	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands  
 See page 3.8-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

	#	T	H	S	e1	e2	e3	$I_{initial}$		$I_{final}$	
								A1 Bars 2-#5	A1 Bars 2-#6	A1 Bars 2-#5	A1 Bars 2-#6
<b>Group I</b>	1	8	4	4	11.26	11.26	13.74	39272	39691	38922	39281
	2	10	4	6	11.59	11.26	13.74	39706	40132	39297	39660
	3	12	6	6	11.59	10.26	12.74	39871	40300	39440	39806
	4	14	6	8	11.26	10.26	12.74	40165	40599	39695	40064
	5	16	8	8	11.26	9.26	11.74	40211	40648	39736	40108
	6	18	8	10	10.66	9.26	11.74	40382	40822	39885	40259
<b>Group II</b>	7	8	2	6	11.59	10.26	14.74	39271	39691	38921	39280
	8	10	2	8	11.76	10.26	14.74	39707	40133	39297	39660
	9	12	4	8	11.26	11.26	13.74	40002	40432	39553	39919
	10	14	4	10	11.46	9.26	13.74	40165	40599	39695	40064
	11	16	6	10	11.46	8.26	12.74	40211	40648	39736	40108
	12	18	6	12	10.93	8.26	12.74	40383	40823	39886	40260
	13	20	6	14	10.83	6.26	12.74	40331	40773	39843	40219

## LRFD Bridge Design Guidelines

### Section Properties Beam Type 2 -- 8" Web

Section Area=	374.9	in <sup>2</sup>
Section $Y_b$ =	14.41	in
$I_{nontransformed}$ =	39,632	in <sup>4</sup>
Depth=	32	in
Strand Size=	0.6	in
$f'_{ci}$ =	5	ksi
$f'_c$ =	7	ksi

NOTE: # = strand pattern number

T = total number of strands

H = number of harped strands

S = number of straight strands

See page 3.8-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

	#	T	H	S	e1	e2	e3	$I_{initial}$		$I_{final}$	
								A1 Bars	A1 Bars	A1 Bars	A1 Bars
								2-#5	2-#6	2-#5	2-#6
<b>Group I</b>	1	8	4	4	11.41	11.41	13.59	42114	42525	41761	42113
	2	10	4	6	11.74	11.41	13.59	42561	42977	42146	42502
	3	12	6	6	11.74	10.41	12.59	42734	43154	42296	42654
	4	14	6	8	11.41	10.41	12.59	43039	43463	42560	42921
	5	16	8	8	11.41	9.41	11.59	43091	43518	42607	42970
	6	18	8	10	10.81	9.41	11.59	43270	43700	42764	43129
<b>Group II</b>	7	8	2	6	11.74	10.41	14.59	42114	42525	41761	42112
	8	10	2	8	11.91	10.41	14.59	42562	42978	42147	42502
	9	12	4	8	11.41	11.41	13.59	42867	43288	42411	42769
	10	14	4	10	11.61	9.41	13.59	43039	43463	42560	42921
	11	16	6	10	11.61	8.41	12.59	43091	43518	42607	42970
	12	18	6	12	11.08	8.41	12.59	43271	43701	42765	43130
	13	20	6	14	10.98	6.41	12.59	43224	43655	42725	43092

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 3 -- 6" Web

Section Area=	381.9	in <sup>2</sup>
Section Y <sub>b</sub> =	17.08	in
I <sub>nontransformed</sub> =	61,841	in <sup>4</sup>
Depth=	39	in
Strand Size=	0.6	in
$f'_{ci}$ =	5	ksi
$f'_c$ =	7	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands  
 See page 3.8-1 for definitions of e1, e2, e3, I<sub>initial</sub>, and I<sub>final</sub>.

Cont.	Span	#	T	H	S	e1	e2	e3	I <sub>initial</sub>		I <sub>final</sub>	
									A1 Bars 2-#5	A1 Bars 2-#6	A1 Bars 2-#5	A1 Bars 2-#6
<b>Group I</b>	1	8	4	4	13.08	14.08	17.92	65603	66291	65068	65656	
	2	10	4	6	13.75	14.08	17.92	66265	66962	65638	66233	
	3	12	4	8	13.58	14.08	17.92	66753	67457	66060	66660	
	4	14	6	8	13.58	13.08	16.92	67077	67787	66341	66945	
	5	16	6	10	13.48	13.08	16.92	67555	68271	66755	67364	
	6	18	8	10	13.48	12.08	15.92	67723	68444	66903	67516	
	7	20	8	12	13.08	12.08	15.92	68042	68769	67182	67799	
	8	22	8	14	12.51	12.08	15.92	68218	68949	67336	67957	
	9	24	10	14	12.51	11.08	14.92	68260	68994	67376	67998	
<b>Group II</b>	10	8	2	6	13.75	13.08	18.92	65604	66292	65068	65657	
	11	10	2	8	14.08	13.08	18.92	66264	66961	65637	66232	
	12	12	2	10	13.88	13.08	18.92	66753	67457	66060	66660	
	13	14	4	10	13.48	14.08	17.92	67236	67946	66477	67082	
	14	16	4	12	13.75	12.08	17.92	67556	68272	66756	67366	
	15	18	6	12	13.75	11.08	16.92	67725	68445	66904	67517	
	16	20	6	14	13.37	11.08	16.92	68045	68771	67184	67800	
	17	22	6	16	12.83	11.08	16.92	68217	68948	67336	67956	
	18	24	8	16	12.83	10.08	15.92	68259	68993	67375	67998	

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 3 -- 7" Web

Section Area=	420.9	in <sup>2</sup>
Section Y <sub>b</sub> =	17.31	in
I <sub>nontransformed</sub> =	66,991	in <sup>4</sup>
Depth=	39	in
Strand Size=	0.6	in
$f'_{ci}$ =	5	ksi
$f'_c$ =	7	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands  
 See page 3.8-1 for definitions of e1, e2, e3, I<sub>initial</sub>, and I<sub>final</sub>.

Cont.	Span	#	T	H	S	e1	e2	e3	I <sub>initial</sub>		I <sub>final</sub>	
									A1 Bars 2-#5	A1 Bars 2-#6	A1 Bars 2-#5	A1 Bars 2-#6
<b>Group I</b>	1	8	4	4	13.31	14.31	17.69	70792	71464	70251	70826	
	2	10	4	6	13.98	14.31	17.69	71477	72155	70841	71420	
	3	12	4	8	13.81	14.31	17.69	71985	72670	71279	71864	
	4	14	6	8	13.81	13.31	16.69	72326	73016	71575	72163	
	5	16	6	10	13.71	13.31	16.69	72823	73520	72006	72599	
	6	18	8	10	13.71	12.31	15.69	73006	73707	72166	72762	
	7	20	8	12	13.31	12.31	15.69	73342	74049	72459	73060	
	8	22	8	14	12.74	12.31	15.69	73532	74242	72626	73229	
	9	24	10	14	12.74	11.31	14.69	73584	74298	72675	73280	
<b>Group II</b>	10	8	2	6	13.98	13.31	18.69	70793	71465	70252	70826	
	11	10	2	8	14.31	13.31	18.69	71476	72155	70840	71420	
	12	12	2	10	14.11	13.31	18.69	71985	72670	71279	71864	
	13	14	4	10	13.71	14.31	17.69	72487	73178	71714	72303	
	14	16	4	12	13.98	12.31	17.69	72825	73522	72007	72600	
	15	18	6	12	13.98	11.31	16.69	73007	73708	72167	72764	
	16	20	6	14	13.60	11.31	16.69	73344	74051	72461	73061	
	17	22	6	16	13.06	11.31	16.69	73531	74242	72625	73229	
	18	24	8	16	13.06	10.31	15.69	73584	74298	72674	73280	

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 3 -- 8" Web

Section Area=	459.9	in <sup>2</sup>
Section Y <sub>b</sub> =	17.49	in
I <sub>nontransformed</sub> =	72,106	in <sup>4</sup>
Depth=	39	in
Strand Size=	0.6	in
$f'_{ci}$ =	5	ksi
$f'_c$ =	7	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands  
 See page 3.8-1 for definitions of e1, e2, e3, I<sub>initial</sub>, and I<sub>final</sub>.

Cont.	Span	#	T	H	S	e1	e2	e3	I <sub>initial</sub>		I <sub>final</sub>	
									A1 Bars 2-#5	A1 Bars 2-#6	A1 Bars 2-#5	A1 Bars 2-#6
<b>Group I</b>	1	8	4	4	13.49	14.49	17.51	75940	76598	75394	75957	
	2	10	4	6	14.16	14.49	17.51	76642	77307	75999	76567	
	3	12	4	8	13.99	14.49	17.51	77166	77837	76451	77023	
	4	14	6	8	13.99	13.49	16.51	77520	78196	76758	77334	
	5	16	6	10	13.89	13.49	16.51	78034	78716	77203	77783	
	6	18	8	10	13.89	12.49	15.51	78229	78914	77373	77956	
	7	20	8	12	13.49	12.49	15.51	78580	79270	77678	78265	
	8	22	8	14	12.92	12.49	15.51	78781	79475	77855	78445	
	9	24	10	14	12.92	11.49	14.51	78843	79540	77911	78504	
<b>Group II</b>	10	8	2	6	14.16	13.49	18.51	75941	76599	75395	75958	
	11	10	2	8	14.49	13.49	18.51	76641	77306	75998	76566	
	12	12	2	10	14.29	13.49	18.51	77166	77837	76451	77023	
	13	14	4	10	13.89	14.49	17.51	77684	78361	76899	77476	
	14	16	4	12	14.16	12.49	17.51	78036	78718	77204	77785	
	15	18	6	12	14.16	11.49	16.51	78230	78916	77374	77957	
	16	20	6	14	13.78	11.49	16.51	78582	79273	77680	78267	
	17	22	6	16	13.24	11.49	16.51	78780	79475	77854	78444	
	18	24	8	16	13.24	10.49	15.51	78842	79540	77911	78503	

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 4 -- 6" Web

Section Area=	428.9	in <sup>2</sup>
Section Y <sub>b</sub> =	19.54	in
I <sub>nontransformed</sub> =	92,450	in <sup>4</sup>
Depth=	45	in
Strand Size=	0.6	in
$f'_{ci}$ =	5	ksi
$f'_c$ =	7	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands

See page 3.8-1 for definitions of e1, e2, e3, I<sub>initial</sub>, and I<sub>final</sub>.

Cont.								I <sub>initial</sub>		I <sub>final</sub>	
	Span	#	T	H	S	e1	e2	e3	A1 Bars 2-#5	A1 Bars 2-#6	A1 Bars 2-#5
<b>Group I</b>	1	8	4	4	15.54	16.54	21.46	97723	98691	96972	97800
	2	10	4	6	16.21	16.54	21.46	98623	99602	97748	98583
	3	12	4	8	16.04	16.54	21.46	99318	100305	98347	99189
	4	14	6	8	16.04	15.54	20.46	99818	100812	98780	99627
	5	16	6	10	15.94	15.54	20.46	100497	101501	99369	100223
	6	18	8	10	15.94	14.54	19.46	100803	101818	99640	100499
	7	20	8	12	15.54	14.54	19.46	101297	102314	100066	100930
	8	22	8	14	14.97	14.54	19.46	101611	102634	100341	101210
	9	24	8	16	15.29	12.54	19.46	101761	102789	100475	101347
	10	26	10	16	15.29	11.54	18.46	101762	102794	100480	101356
	11	28	10	18	15.32	9.54	18.46	101633	102667	100372	101250
<b>Group II</b>	12	8	2	6	16.21	15.54	22.46	97724	98692	96973	97801
	13	10	2	8	16.54	15.54	22.46	98622	99601	97747	98582
	14	12	4	8	16.04	16.54	21.46	99318	100305	98347	99189
	15	14	4	10	15.94	16.54	21.46	100005	101001	98941	99790
	16	16	4	12	16.21	14.54	21.46	100499	101503	99370	100224
	17	16	6	10	15.94	15.54	20.46	100497	101501	99369	100223
	18	18	6	12	16.21	13.54	20.46	100810	101819	99641	100500
	19	20	6	14	15.83	13.54	20.46	101300	102317	100068	100932
	20	22	6	16	15.29	13.54	20.46	101610	102633	100340	101209
	21	24	6	18	15.32	11.54	20.46	101762	102790	100476	101349
	22	26	6	20	15.14	9.54	20.46	101762	102794	100480	101356
	23	26	8	18	15.32	10.54	19.46	101764	102796	100482	101357
	24	28	6	22	14.81	7.54	20.46	101629	102663	100369	101246
	25	28	8	20	15.14	8.54	19.46	101631	102666	100371	101248
	26	30	8	22	14.81	6.54	19.46	101381	102417	100158	101037
	27	32	8	24	14.37	4.54	19.46	101033	102069	99860	100739

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 4 -- 7" Web

Section Area=	473.9 in <sup>2</sup>
Section Y <sub>b</sub> =	19.82 in
I <sub>nontransformed</sub> =	100,400 in <sup>4</sup>
Depth=	45 in
Strand Size=	0.6 in
f' <sub>ci</sub> =	5 ksi
f' <sub>c</sub> =	7 ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands

See page 3.8-1 for definitions of e1, e2, e3, I<sub>initial</sub>, and I<sub>final</sub>.

Cont.								I <sub>initial</sub>		I <sub>final</sub>		
	Span	#	T	H	S	e1	e2	e3	A1 Bars 2-#5	A1 Bars 2-#6	A1 Bars 2-#5	A1 Bars 2-#6
<b>Group I</b>	1	8	4	4	4	15.82	16.82	21.18	105729	106673	104971	105778
	2	10	4	6	6	16.49	16.82	21.18	106661	107614	105773	106587
	3	12	4	8	8	16.32	16.82	21.18	107384	108345	106396	107216
	4	14	6	8	8	16.32	15.82	20.18	107903	108876	106850	107675
	5	16	6	10	10	16.22	15.82	20.18	108617	109593	107464	108295
	6	18	8	10	10	16.22	14.82	19.18	108950	109931	107753	108589
	7	20	8	12	12	15.82	14.82	19.18	109464	110453	108201	109041
	8	22	8	14	14	15.25	14.82	19.18	109801	110795	108495	109340
	9	24	8	16	16	15.57	12.82	19.18	109968	110967	108644	109492
	10	26	10	16	16	15.57	14.82	18.18	109984	110986	108661	109512
	11	28	10	18	18	15.60	9.82	18.18	109864	110869	108562	109415
<b>Group II</b>	12	8	2	6	6	16.49	15.82	22.18	105730	106674	104971	105779
	13	10	2	8	8	16.82	15.82	22.18	106660	107613	105772	106586
	14	12	4	8	8	16.32	16.82	21.18	107384	108345	106396	107216
	15	14	4	10	10	16.22	16.82	21.18	108100	109069	107015	107841
	16	16	4	12	12	16.49	14.82	21.18	108619	109595	107465	108296
	17	16	6	10	10	16.22	15.82	20.18	108617	109593	107464	108295
	18	18	6	12	12	16.49	13.82	20.18	108951	109933	107755	108590
	19	20	6	14	14	16.11	13.82	20.18	109467	110456	108203	109044
	20	22	6	16	16	15.57	13.82	20.18	109800	110794	108494	109339
	21	24	6	18	18	15.60	11.82	20.18	109970	110969	108645	109494
	22	26	6	20	20	15.42	9.82	20.18	109984	110986	108661	109512
	23	26	8	18	18	15.60	10.82	19.18	109985	110988	108663	109514
	24	28	6	22	22	15.09	7.82	20.18	109860	110865	108559	109411
	25	28	8	20	20	15.42	8.82	19.18	109862	110867	108561	109413
	26	30	8	22	22	15.09	6.82	19.18	109618	110624	108353	109207
	27	32	8	24	24	14.65	4.82	19.18	109271	110278	108056	108910

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 4 -- 8" Web

Section Area=	518.9	in <sup>2</sup>
Section $Y_b$ =	20.06	in
$I_{nontransformed}$ =	108,288	in <sup>4</sup>
Depth=	45	in
Strand Size=	0.6	in
$f'_{ci}$ =	5	ksi
$f'_c$ =	7	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands

See page 3.8-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

Cont.	Span	#	T	H	S	e1	e2	e3	$I_{initial}$		$I_{final}$	
									A1 Bars 2-#5	A1 Bars 2-#6	A1 Bars 2-#5	A1 Bars 2-#6
Group I	1	8	4	4	16.06	17.06	20.94	113668	114591	112902	113692	
	2	10	4	6	16.73	17.06	20.94	114627	115559	113727	114523	
	3	12	4	8	16.56	17.06	20.94	115375	116314	114372	115174	
	4	14	6	8	16.56	16.06	19.94	115921	116866	114844	115651	
	5	16	6	10	16.46	16.06	19.94	116655	117608	115480	116291	
	6	18	8	10	16.46	15.06	18.94	117007	117965	115786	116601	
	7	20	8	12	16.06	15.06	18.94	117544	118509	116252	117073	
	8	22	8	14	15.49	15.06	18.94	117900	118870	116563	117387	
	9	24	8	16	15.81	13.06	18.94	118084	119058	116725	117553	
	10	26	10	16	15.81	12.06	17.94	118112	119089	116754	117584	
	11	28	10	18	15.84	10.06	17.94	118001	118981	116662	117494	
Group II	12	8	2	6	16.73	16.06	21.94	113669	114592	112903	113693	
	13	10	2	8	17.06	16.06	21.94	114626	115558	113726	114522	
	14	12	4	8	16.56	17.06	20.94	115375	116314	114372	115174	
	15	14	4	10	16.46	17.06	20.94	116116	117062	115012	115819	
	16	16	4	12	16.73	15.06	20.94	116657	117610	115481	116293	
	17	16	6	10	16.46	16.06	19.94	116655	117608	115480	116291	
	18	18	6	12	16.73	14.06	19.94	117009	117967	115787	116603	
	19	20	6	14	16.35	14.06	19.94	117547	118512	116255	117075	
	20	22	6	16	15.81	14.06	19.94	117899	118869	116562	117387	
	21	24	6	18	15.84	12.06	19.94	118085	119059	116727	117554	
	22	26	6	20	15.66	10.06	19.94	118112	119089	116754	117584	
	23	26	8	18	15.84	11.06	18.94	118113	119091	116755	117585	
	24	28	6	22	15.33	8.06	19.94	117997	118977	116659	117490	
	25	28	8	20	15.66	9.06	18.94	117999	118979	116661	117493	
	26	30	8	22	15.33	7.06	18.94	117760	118742	116458	117291	
	27	32	8	24	14.89	5.06	18.94	117415	118397	116163	116996	

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 6 -- 6.5" Web

Section Area=	643.6	in <sup>2</sup>
Section $Y_b$ =	25.92	in
$I_{nontransformed}$ =	235,735	in <sup>4</sup>
Depth=	54	in
Strand Size=	0.6	in
$f'_{ci}$ =	5	ksi
$f'_c$ =	7	ksi

NOTE: # = strand pattern number

T = total number of strands

H = number of harped strands

S = number of straight strands

See page 3.8-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

								$I_{initial}$	$I_{final}$
	#	T	H	S	e1	e2	e3	A1 Bars 2-#6	A1 Bars 2-#6
<b>Group</b>	1	14	4	10	23.52	22.92	23.08	251047	248880
<b>I</b>	2	16	4	12	23.25	22.92	23.08	252425	250070
	3	18	6	12	23.25	21.92	22.08	253525	251022
	4	20	6	14	23.06	21.92	22.08	254886	252199
	5	22	6	16	22.92	21.92	22.08	256238	253370
	6	24	8	16	22.92	20.92	21.08	257053	254081
	7	26	8	18	22.59	20.92	21.08	258130	255017
	8	28	8	20	22.32	20.92	21.08	259191	255940
	9	30	10	20	22.32	19.92	20.08	259751	256433
	10	32	10	22	22.10	19.92	20.08	260803	257350
	11	34	10	24	21.75	19.92	20.08	261604	258052
	12	36	10	26	21.46	19.92	20.08	262412	258760
	13	38	12	26	21.46	18.92	19.08	262739	259053

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 6 -- 7.5" Web

Section Area=	697.6	in <sup>2</sup>
Section $Y_b$ =	26.00	in
$I_{nontransformed}$ =	248,915	in <sup>4</sup>
Depth=	54	in
Strand Size=	0.6	in
$f'_{ci}$ =	5	ksi
$f'_c$ =	7	ksi

NOTE: # = strand pattern number

T = total number of strands

H = number of harped strands

S = number of straight strands

See page 3.8-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

								$I_{initial}$	$I_{final}$
	#	T	H	S	e1	e2	e3	A1 Bars 2-#6	A1 Bars 2-#6
<b>Group</b>	1	14	4	10	23.60	23.00	23.00	264293	262115
<b>I</b>	2	16	4	12	23.33	23.00	23.00	265686	263318
	3	18	6	12	23.33	22.00	22.00	266601	264281
	4	20	6	14	23.14	22.00	22.00	268173	265473
	5	22	6	16	23.00	22.00	22.00	269548	266658
	6	24	8	16	23.00	21.00	21.00	270378	267381
	7	26	8	18	22.67	21.00	21.00	271472	268330
	8	28	8	20	22.40	21.00	21.00	272551	269269
	9	30	10	20	22.40	20.00	20.00	273125	269772
	10	32	10	22	22.18	20.00	20.00	274195	270705
	11	34	10	24	21.83	20.00	20.00	275014	271420
	12	36	10	26	21.54	20.00	20.00	275839	272143
	13	38	12	26	21.54	19.00	19.00	276180	272447

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 6 -- 8.5" Web

Section Area=	751.6	in <sup>2</sup>
Section $Y_b$ =	26.07	in
$I_{nontransformed}$ =	262,087	in <sup>4</sup>
Depth=	54	in
Strand Size=	0.6	in
$f'_{ci}$ =	5	ksi
$f'_c$ =	7	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands

See page 3.8-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

	#	T	H	S	e1	e2	e3	$I_{initial}$ A1 Bars 2-#6	$I_{final}$ A1 Bars 2-#6
<b>Group</b>	1	14	4	10	23.67	23.07	22.93	277522	275336
<b>I</b>	2	16	4	12	23.40	23.07	22.93	278930	276549
	3	18	6	12	23.40	22.07	21.93	280057	277523
	4	20	6	14	23.21	22.07	21.93	281449	278727
	5	22	6	16	23.07	22.07	21.93	282834	279925
	6	24	8	16	23.07	21.07	20.93	283678	280658
	7	26	8	18	22.74	21.07	20.93	284786	281620
	8	28	8	20	22.47	21.07	20.93	285881	282571
	9	30	10	20	22.47	20.07	19.93	286468	283085
	10	32	10	22	22.25	20.07	19.93	287554	284030
	11	34	10	24	21.90	20.07	19.93	288388	284758
	12	36	10	26	21.61	20.07	19.93	289228	285493
	13	38	12	26	21.61	19.07	18.93	289581	285807

# LRFD Bridge Design Guidelines

## Section Properties

### Beam Type 7 -- 6" Web

#### Bulb Tee Girder

Section Area=	787.4	in <sup>2</sup>
Section $Y_b$ =	37.58	in
$I_{nontransformed}$ =	571,047	in <sup>4</sup>
Depth=	72.5	in
Strand Size=	0.6	in
$f'_{ci}$ =	5	ksi
$f'_c$ =	7	ksi

NOTE: # = strand pattern number  
 T = total number of strands  
 H = number of harped strands  
 S = number of straight strands

See page 3.8-1 for definitions of e1, e2, e3,  $I_{initial}$ , and  $I_{final}$ .

Cont.								$I_{initial}$	$I_{final}$
Span	#	T	H	S	e1	e2	e3	A1 Bars 4-#6	A1 Bars 4-#6
<b>Group</b>	1	14	4	10	35.58	34.58	29.92	609994	604448
<b>I</b>	2	16	4	12	35.25	34.58	29.92	613316	607307
	3	18	6	12	35.25	33.58	28.92	616196	609790
	4	20	6	14	35.01	33.58	28.92	619469	612612
	5	22	6	16	34.83	33.58	28.92	622719	615417
	6	24	8	16	34.83	32.58	27.92	625140	617512
	7	26	8	18	34.69	32.58	27.92	628347	620286
	8	28	8	20	34.58	32.58	27.92	631536	623046
	9	30	10	20	34.58	31.58	26.92	633518	624769
	10	32	10	22	34.31	31.58	26.92	636280	627166
	11	34	10	24	34.08	31.58	26.92	639012	629539
	12	36	10	26	33.89	31.58	26.92	641737	631909
	13	38	10	28	33.58	31.58	26.92	644052	633926
	14	40	12	28	33.58	30.58	25.92	645607	635289

3.9 Girder Reinforcement  
Reinforcing Dimensions

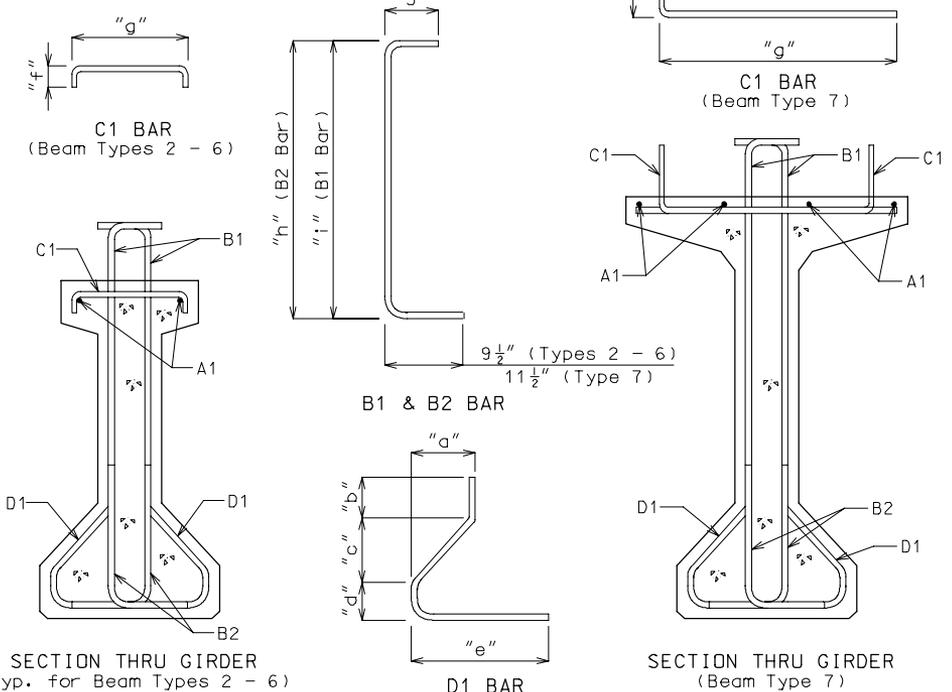
Details

TABLE OF DIMENSIONS													
	BEAM TYPE 2			BEAM TYPE 3			BEAM TYPE 4			BEAM TYPE 6			BEAM TYPE 7
WEB	6"	7"	8"	6"	7"	8"	6"	7"	8"	6½"	7½"	8½"	6"
"a"	5½"	5½"	5½"	5½"	5½"	5½"	5½"	5½"	5½"	8¼"	8¼"	8¼"	10"
"b"	4"	4"	4"	4"	4"	4"	4"	4"	4"	4"	4"	4"	4"
"c"	6"	6"	6"	6"	6"	6"	6"	6"	6"	7"	7"	7"	4½"
"d"	3¼"	3¼"	3¼"	5⅛"	5⅛"	5⅛"	6¼"	6¼"	6¼"	4⅛"	4⅛"	4⅛"	4⅛"
"e"	13"	14"	15"	13"	14"	15"	13"	14"	15"	18"	19"	20"	20"
"f"	2"	2"	2"	2"	2"	2"	2"	2"	2"	3"	3"	3"	7"
"g"	11"	12"	13"	11"	12"	13"	11"	12"	13"	22"	23"	24"	2'-11½"
"h"	2'-6"	2'-6"	2'-6"	3'-1"	3'-1"	3'-1"	3'-7"	3'-7"	3'-7"	4'-4"	4'-4"	4'-4"	5'-10½"
"i"	3'-0½"	3'-0½"	3'-0½"	3'-7½"	3'-7½"	3'-7½"	4'-1½"	4'-1½"	4'-1½"	4'-10½"	4'-10½"	4'-10½"	6'-5"

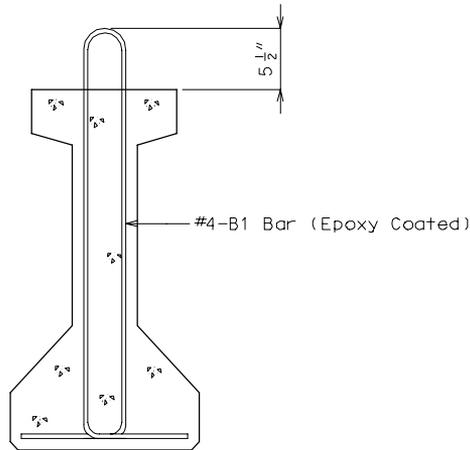
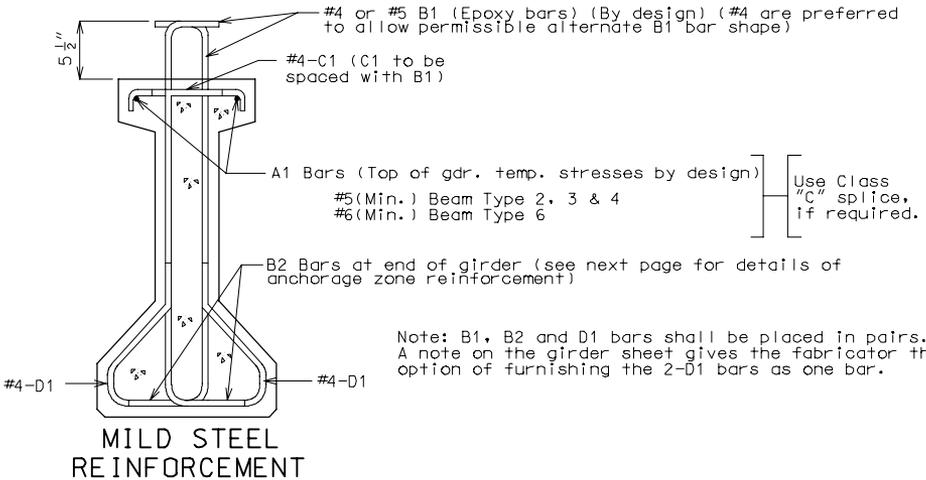
Note: Dimensions shown above are out to out.

TOTAL BAR LENGTH													
	BEAM TYPE 2			BEAM TYPE 3			BEAM TYPE 4			BEAM TYPE 6			BEAM TYPE 7
WEB	6"	7"	8"	6"	7"	8"	6"	7"	8"	6½"	7½"	8½"	6"
B1	4'-1"	4'-1"	4'-1"	4'-8"	4'-8"	4'-8"	5'-2"	5'-2"	5'-2"	5'-11"	5'-11"	5'-11"	7'-8"
B2	3'-6"	3'-6"	3'-6"	4'-1"	4'-1"	4'-1"	4'-7"	4'-7"	4'-7"	5'-4"	5'-4"	5'-4"	7'-0"
C1	13"	14"	15"	13"	14"	15"	13"	14"	15"	2'-2"	2'-3"	2'-4"	3'-6"
D1	2'-4"	2'-5"	2'-6"	2'-5"	2'-6"	2'-7"	2'-7"	2'-8"	2'-9"	3'-0"	3'-1"	3'-2"	3'-1"

Note: For girders that have stepped top flanges, create new B1 and C1 Bars and adjust Bar Lengths for step heights.



Girder Reinforcement (Cont.)



B1 BAR PERMISSIBLE ALTERNATE SHAPE

Note: Place the above detail on Prestress I-Girder sheets only where #4-B1 reinforcing bars are used.

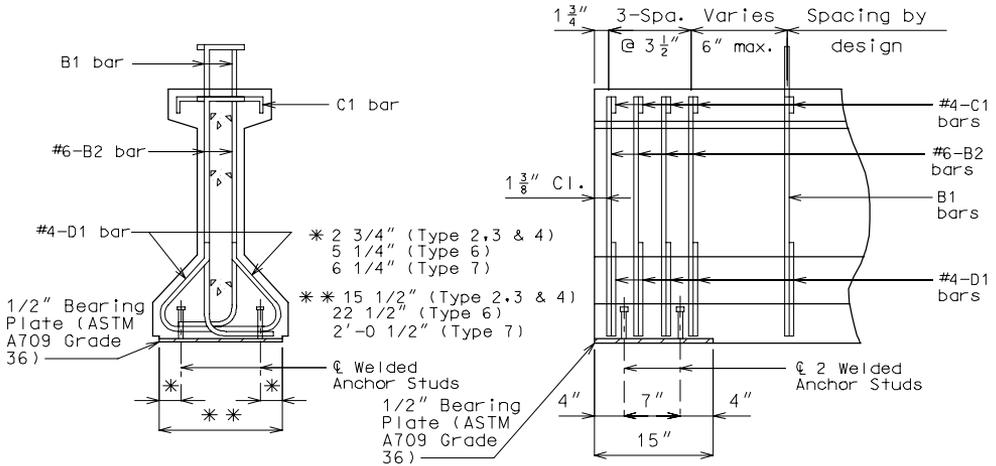
#### Girder Reinforcement (Cont.)

##### Anchorage Zone Reinforcement

The following detail meets the criteria for anchorage zone reinforcement for prestensioned girders for all MoDOT standard girder shapes.

##### Standard P/S Girder End Section For Conventional Concrete Only (\*)

(\*) Use for Type 2, 3, 4, 6 and 7 Girders. End reinforcement must be designed for Type NU Girders.



##### Sole Plate Anchor Studs

The standard 1/2" sole plate will be anchored with four 1/2" x 4" studs min.

If required, increase the number of 1/2" studs to six and space between open B2 bars.

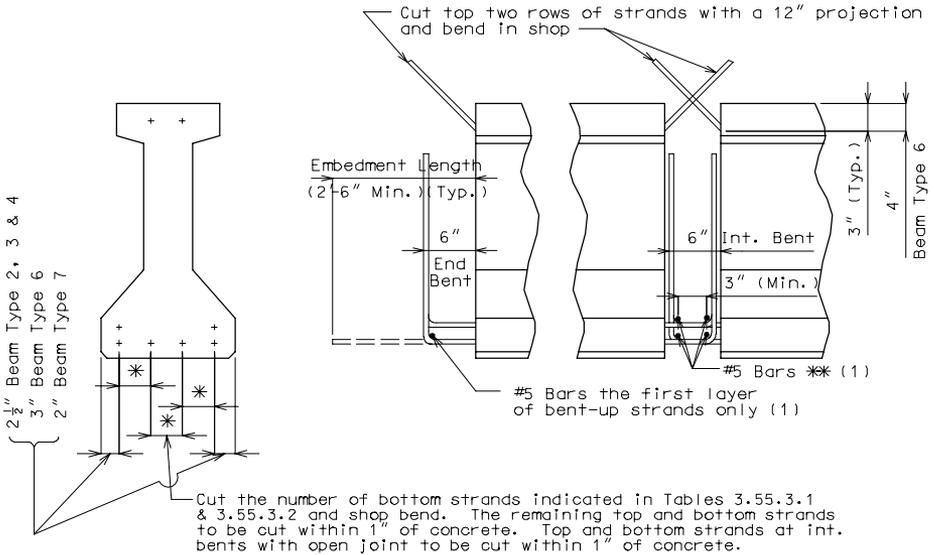
The minimum 1/4" fillet weld between the 1/2" bearing plate and 1-1/2" sole plate is adequate for all cases.

3.10 Bent-Up Strands

Details

Bent-up strands for positive moment connection

Tables 3.55.3.1 and 3.55.3.2 on the next page show the number of bent-up strands for closed and open diaphragms (with a continuous super-structure), respectively. Provide a minimum number of bent-up strands as shown in tables at the bottom of girder ends. These bent-up strands shall be adequate to resist a positive moment over the bents.



\* Varies

\*\* #5 bars typical at each layer of bent-up strands.

(1) #5-strand tie bars normal to girder.

# LRFD Bridge Design Guidelines

### Bent-Up Strands (Cont.)

#### TABLE NO. 3.55.3.1

WEB THICKNESS (INCHES)	NUMBER OF BOTTOM STRANDS FOR POSITIVE MOMENT CONNECTION (C) FOR CLOSED DIAPHRAGMS				
	BEAM TYPE 2	BEAM TYPE 3	BEAM TYPE 4	BEAM TYPE 6	BEAM TYPE 7 (BULB TEE)
6	6	8	10	---	18
6-1/2	---	---	---	14	---
7(A)	8	10	10	---	---
7-1/2(B)	---	---	---	16	---
8(A)	8	10	12	---	---
8-1/2(B)	---	---	---	16	---

#### TABLE NO. 3.55.3.2

WEB THICKNESS (INCHES)	NUMBER OF BOTTOM STRANDS FOR POSITIVE MOMENT CONNECTION (C) FOR OPEN INTERMEDIATE DIAPHRAGMS WITH CONTINUOUS SUPERSTRUCTURE				
	BEAM TYPE 2	BEAM TYPE 3	BEAM TYPE 4	BEAM TYPE 6	BEAM TYPE 7 (BULB TEE)
6	12	16	16	---	22
6-1/2	---	---	---	22	---
7(A)	12	16	16	---	---
7-1/2(B)	---	---	---	22	---
8(A)	12	16	16	---	---
8-1/2(B)	---	---	---	22	---

(A) Modified Beam Type 2, 3 or 4.

(B) Modified Beam Type 6.

(C) If available, otherwise bend all bottom strands.

3.11 Haunching and Girder Steps

**Haunching**

Haunching for a P/S I-Girder bridge is the distance between the top of the girder and the bottom of the slab.

Haunching shall be computed at quarter (1/4) points for bridges with spans less than 75 feet, and at tenth (1/10) points for span 75 feet and longer. A typical theoretical slab haunching diagram as shown below shall be provided on all P/S I-Girder bridges.

A minimum haunch of 1" at the centerline of girder and 1/2" at the edge of the girder flange shall be provided to allow for construction tolerances and normal concrete variations for cip decks. Minimum of 1" shall be below PS panel to allow for adequate flow of concrete below the panel.

A maximum haunch at the centerline of the girder of 2.5" is allowed when prestressed panels are used, and 3.5" when only the cast-in-place option is used. (The maximum joint filler thickness supporting panels is 2"; the remaining haunch thickness will be addressed by varying the slab thickness)

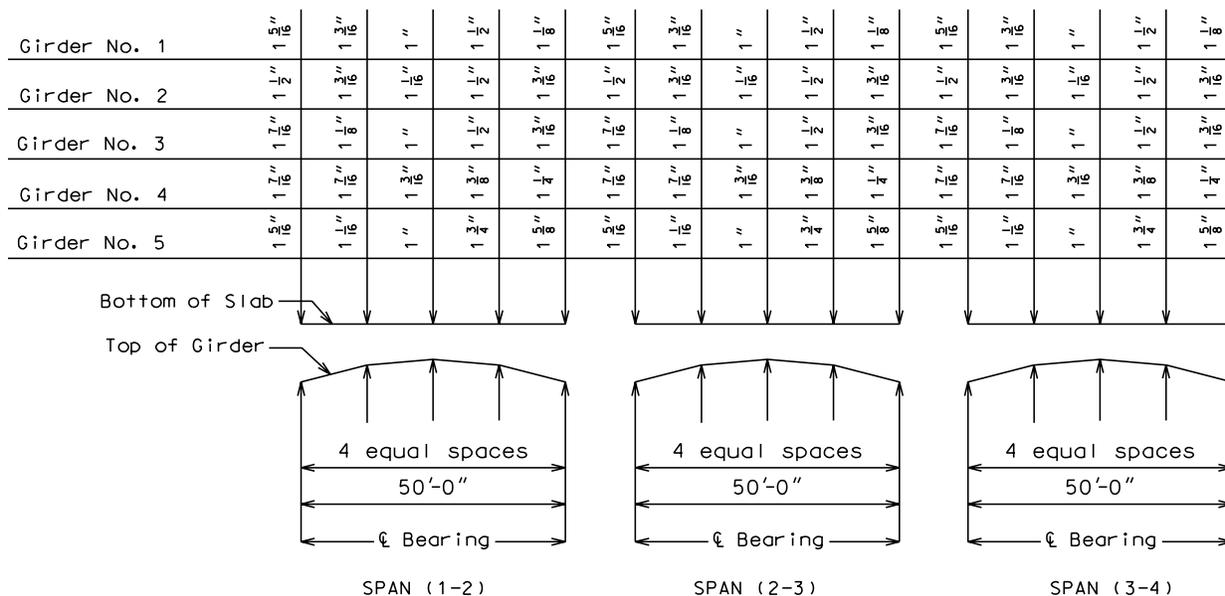


Figure 3.55.3.11.1 Theoretical Slab Haunching Diagram

**Girder Steps**

When haunches greater than 2.5" occur with prestressed panels, steps shall be provided on the girder as shown on the following page, to keep the haunch between 1" and 2". The minimum step height shall be 1/2" with 1/2" increments with no limit of the number of steps. If the steps accumulate to 1" or more, adjust the height of the B1 bars in 1" increments.

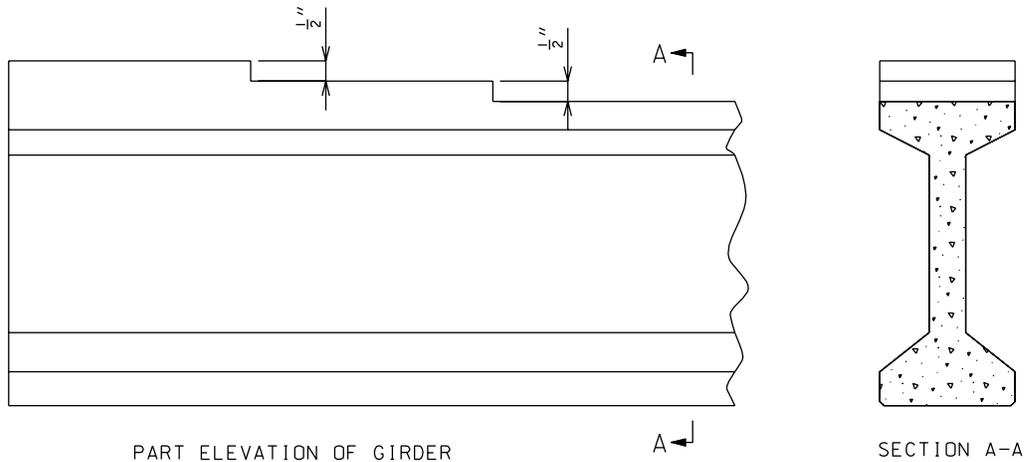


Figure 3.55.3.11.2 Girder Top Flange Step Example

**Top of Girder**

Tops of girders, for bridges with superelevations of more than 2%, shall be sloped across the top flange to match the superelevation as shown below. The minimum thickness of the top flange shall be the standard flange thickness and the overall height at the minimum point shall be the standard girder height.

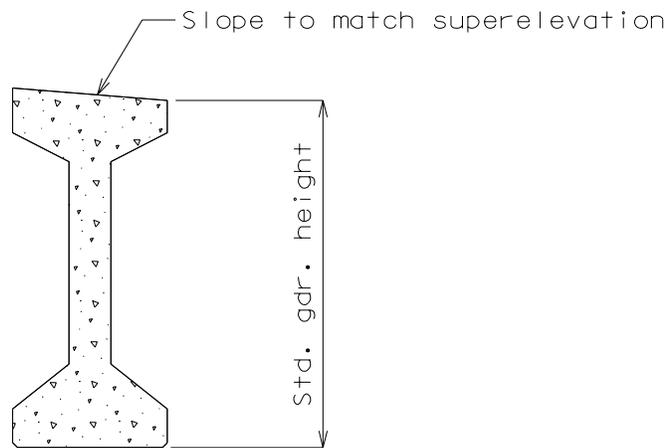
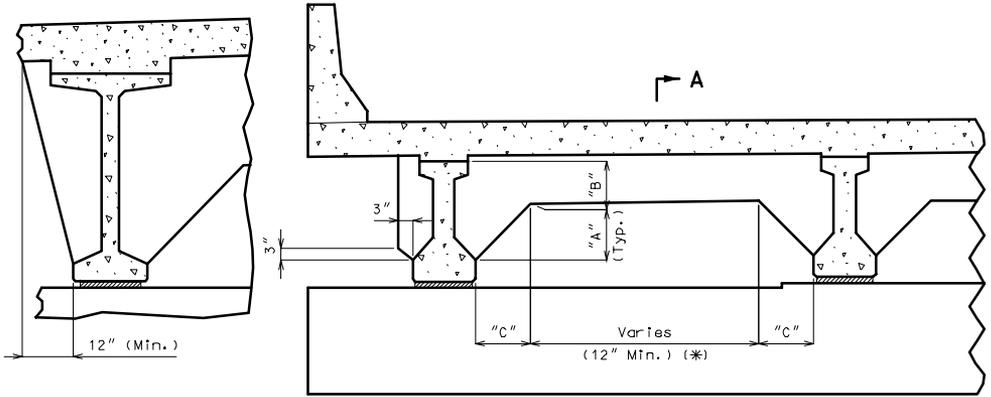


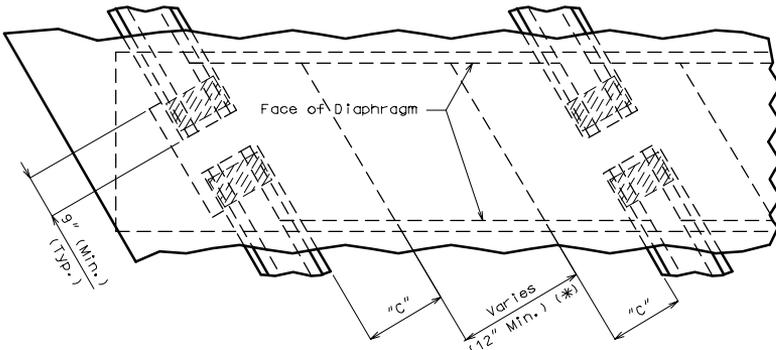
Figure 3.55.3.11.3 Top Flange Slope with Superelevation

3.12 Open Intermediate Bent Diaphragms  
(Expansion Intermediate Bent with Continuous Slab)  
Dimensions:

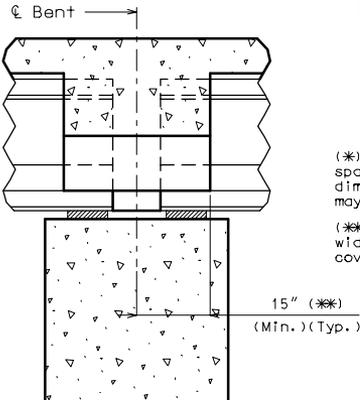


PART ELEVATION FOR BULB TEE GIRDERS

PART ELEVATION



PART PLAN



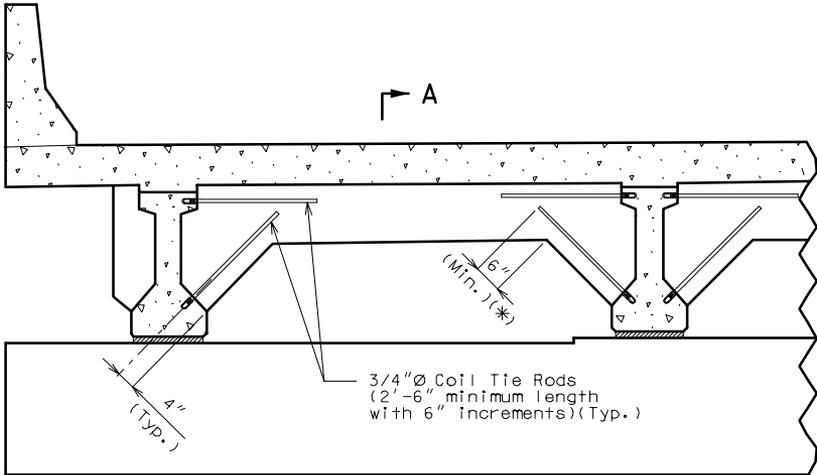
PART SECTION A-A

(\*) For Bulb Tee Girder, spacings less than 8'-8" dimensions "A", "B" & "C" may have to be modified.

(\*\*) Make sure the Diaphragm is wide enough to provide enough cover for the Coll Tie Rods.

GIRDER TYPE	DIMENSIONS		
	"A"	"B"	"C"
TYPE "2" 2'-8"	12"	15"	13"
TYPE "3" 3'-3"	17"	15"	19"
TYPE "4" 3'-9"	19"	18"	21"
TYPE "6" 4'-6"	2'-3"	21"	2'-1"
BULB TEE 6'-0½" *	3'-0"	2'-6½"	2'-9"

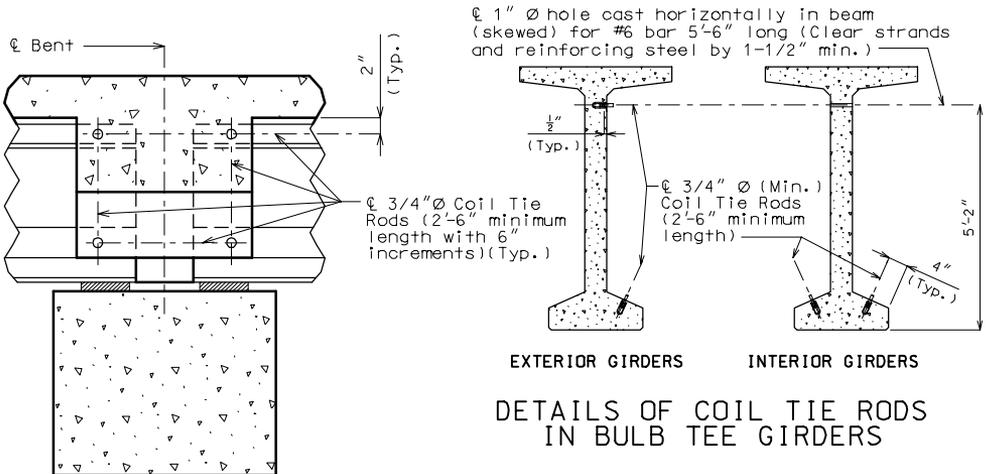
Open Intermediate Bent Diaphragms (Cont.)  
 (Expansion Intermediate Bent with Continuous Slab)  
 Coil Tie Rod:



PART ELEVATION

NOTE: For location of the Coil Tie Rods in a plan view, see LRFD DG Sec. 3.55.3.

(\* ) 6" (Min.) shall be used for all I-Girders and Bulb Tee Girders.

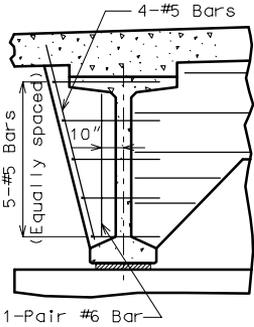


DETAILS OF COIL TIE RODS IN BULB TEE GIRDERS

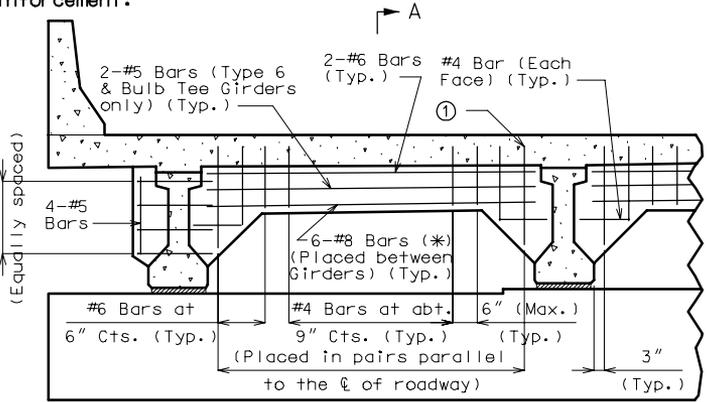
PART SECTION A-A

Open Intermediate Bent Diaphragms (Cont.)  
(Expansion Intermediate Bent with Continuous Slab)  
Reinforcement:

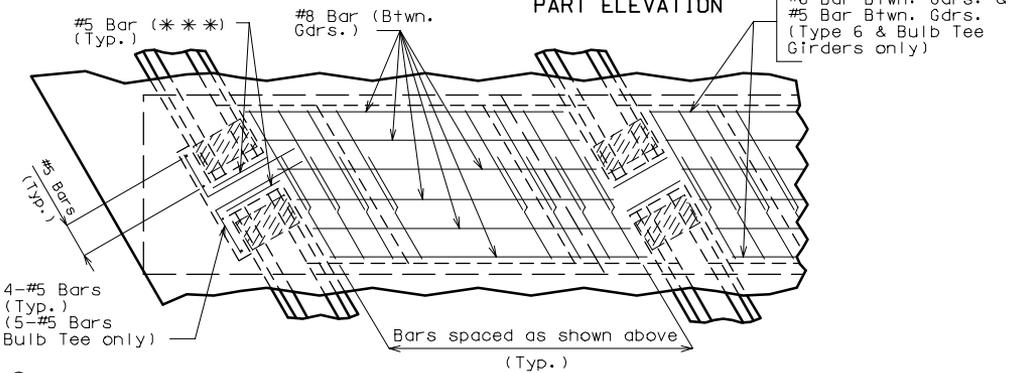
**Details**



**PART ELEVATION FOR BULB TEE GIRDERS**

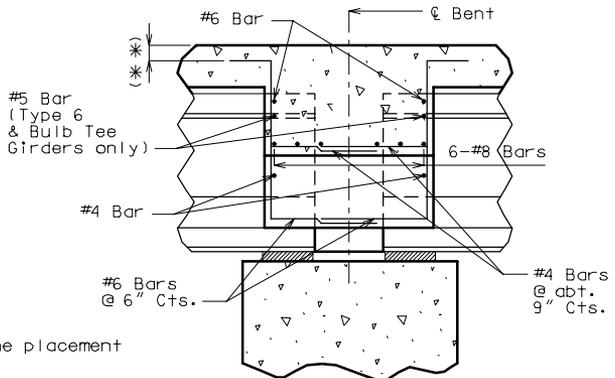


**PART ELEVATION**



**PART PLAN**

① For Bulb Tee Girders, the first #6 Bar shall be placed 10" from the  $\phi$  of Web (Top Flange will prevent some Bars from extending into the Slab).



**PART SECTION A-A**

(\*) See Section "A" for the placement of reinforcement.

(\*\*) Use the same clearance as longitudinal slab steel.

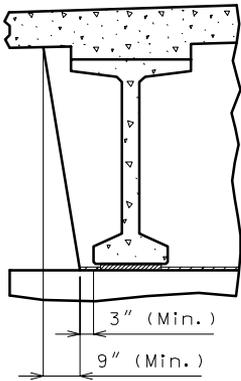
(\*\*\*) #5 Bars for each layer of bent up strands.

# LRFD Bridge Design Guidelines

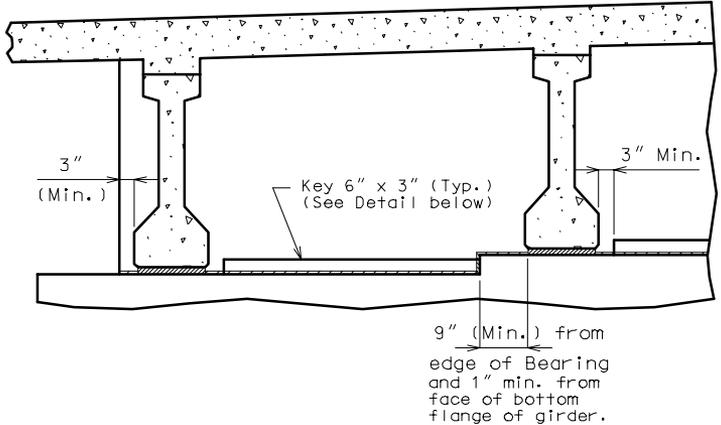
## Prestressed Concrete I-Girders - Section 3.55

### 3.13 Closed Intermediate Bent diaphragms (Fixed Intermediate Bents with Continuous Slab) Dimensions:

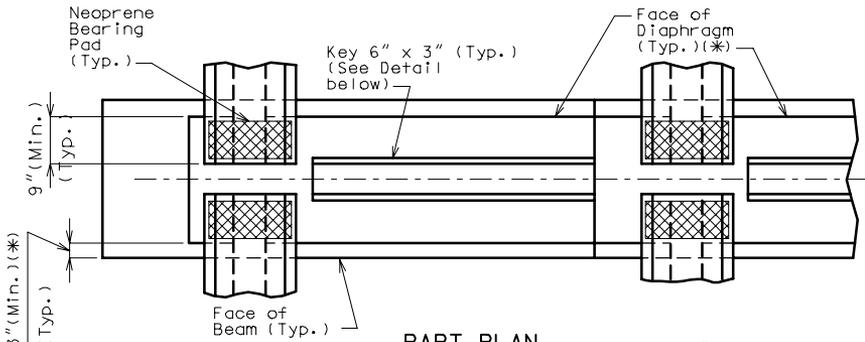
Details



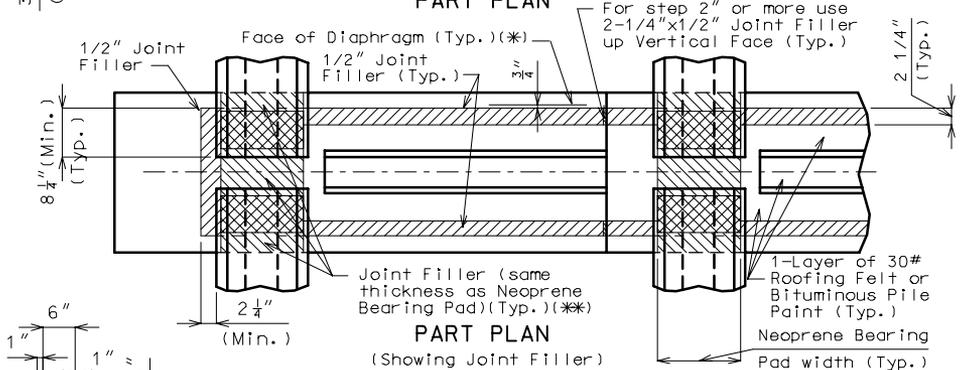
PART ELEVATION FOR  
BULB TEE GIRDERS



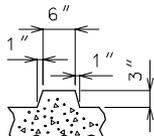
PART ELEVATION



PART PLAN



PART PLAN

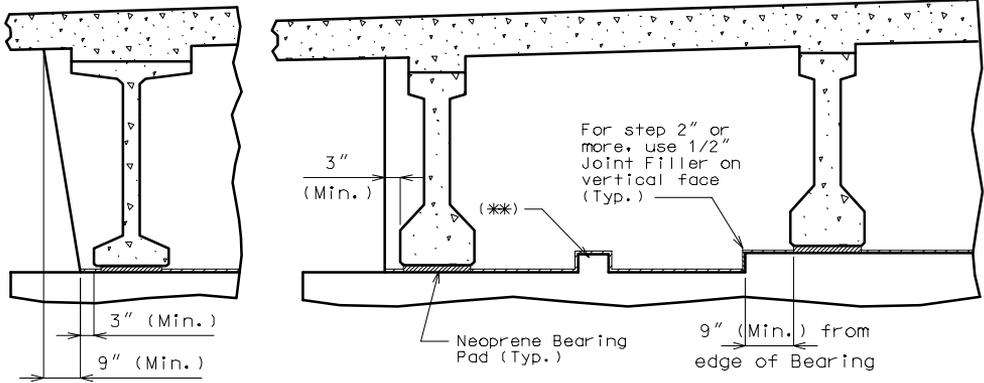


DETAIL OF KEY

(\*) Make flush with Bent Caps, less than 3'-0" wide. For Bent Caps 3'-0" and over, make Diaphragms 2'-6" wide unless skew requires wider Diaphragms to accommodate Coil Ties.

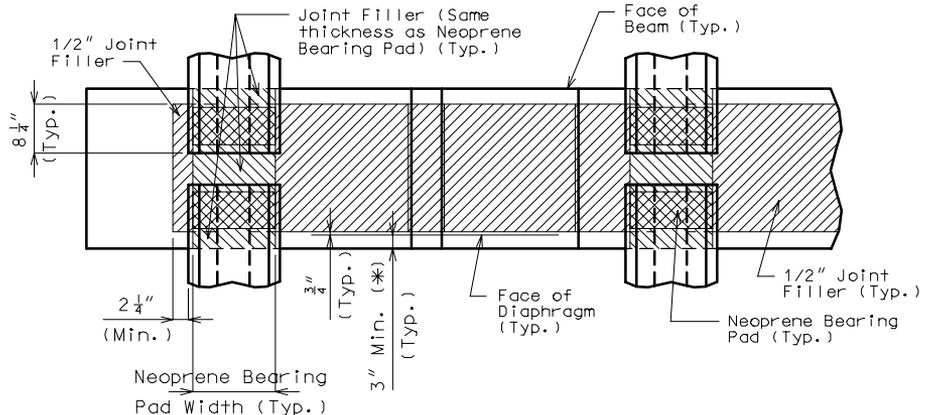
(\*\*) For tapered bearings or for bearings with different thickness use the following note: "Fill area under girders with Joint Filler."

Closed Intermediate Bent Diaphragms (Cont.)  
(Expansion Intermediate Bents with Continuous Slab)  
Dimensions:



PART ELEVATION FOR BULB TEE GIRDERS

PART ELEVATION



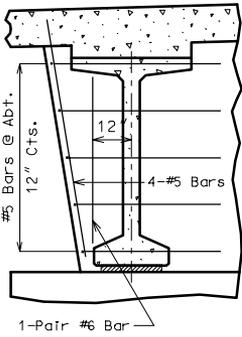
PART PLAN

- (\*) Make flush with Bent Caps less than 3'-0" wide. For Bent Caps 3'-0" and over, make Diaphragm 2'-6" wide unless skew requires wider Diaphragm to accommodate Coil Ties.
- (\*\*) Use Shear Blocks when Bent Cap steps down in one direction or when there are less than two steps in each direction with maximum step height less than 1-1/2" each.

Shear Blocks shall be detailed parallel to the centerline of roadway and shall be designed to resist 0.20 times the tributary weight where tributary weight is defined as the total bent dead load reaction. See this section for shear block design method.

PART LONGITUDINAL ELEVATION

#### Closed Intermediate Bent Diaphragms (Cont.) (Fixed and Expansion Intermediate Bents with Continuous Slab) Reinforcement (Square Structure):



**PART ELEVATION FOR  
BULB TEE GIRDERS**

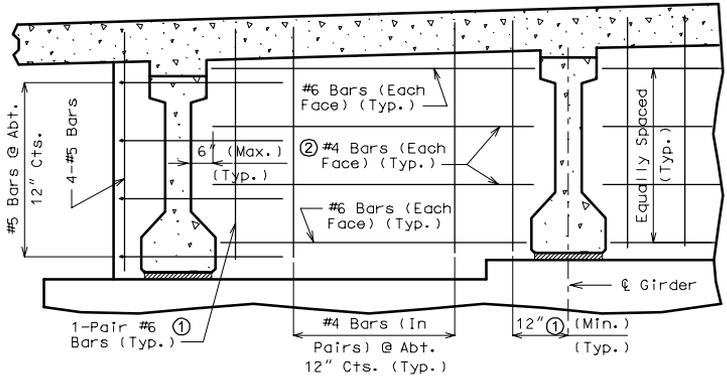
① For Bulb Tee Girders, the #6 Bar shall be a min. of 15" from  $\ell$  of Girder and will not extend past the bottom of the top flange.

② For Bulb Tee Girders, use 3-#4 Bars in each Diaphragm face

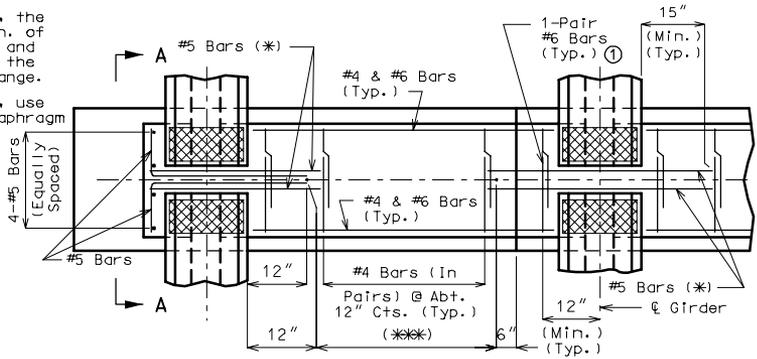
(\*) #5 Bars for each layer of bent up strands.

(\*\*) Use the same clearance as the longitudinal slab steel.

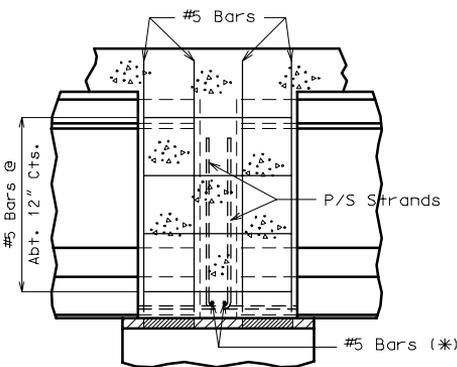
(\*\*\*) By design. Min. #6 Dowel bars @ 12" cts. (Typ.) (Fixed bent only)



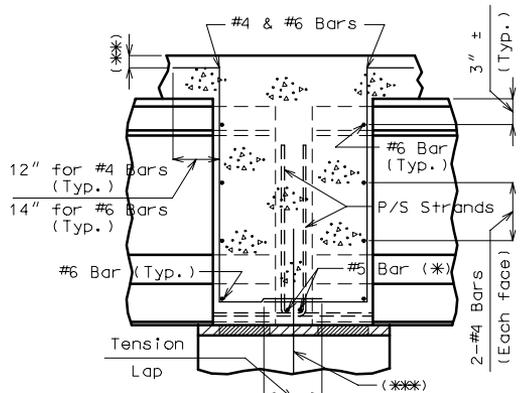
**PART ELEVATION**



**PART PLAN**

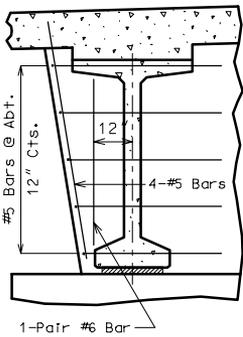


**PART ELEVATION A-A**



**SECTION THRU DIAPHRAGM**

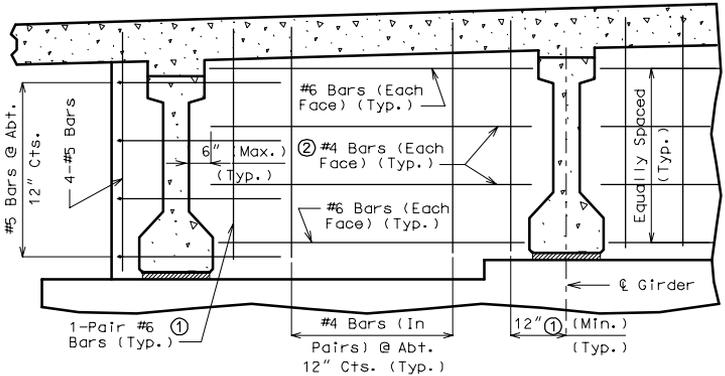
### Closed Intermediate Bent Diaphragms (Cont.) (Fixed and Expansion Intermediate Bents with Continuous Slab Reinforcement (Skewed Structure):



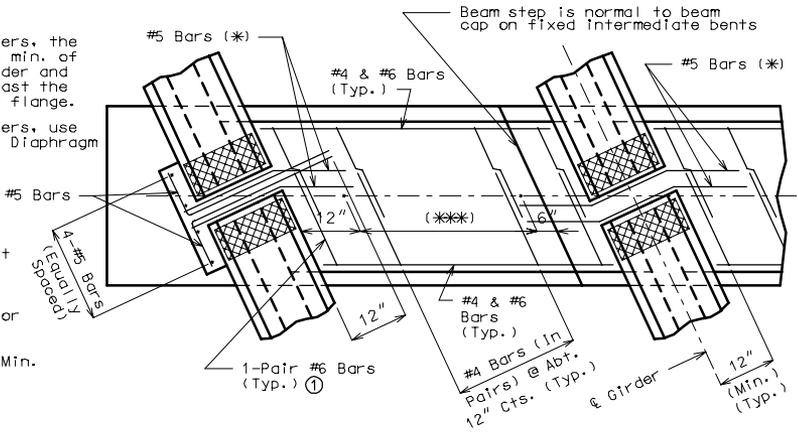
**PART ELEVATION FOR  
BULB TEE GIRDERS**

- ① For Bulb Tee Girders, the #6 Bar shall be a min. of 15" from  $\epsilon$  of Girder and will not extend past the bottom of the top flange.
- ② For Bulb Tee Girders, use 3-#4 Bars in each Diaphragm face

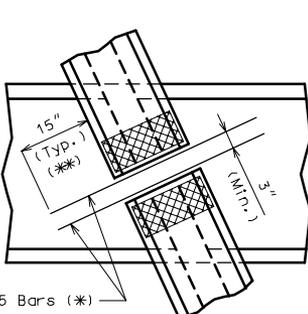
- (\*) #5 Bars for each layer of bent up strands.
- (\*\*) Omit leg on outside of exterior girder.
- (\*\*\*) By design, Min. #6 Dowel bars @ 12" Cts. (Typ.) (Fixed bent only)



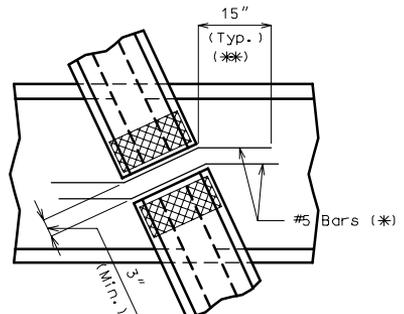
**PART ELEVATION**



**PART PLAN**



**SKEWS THRU 25°**

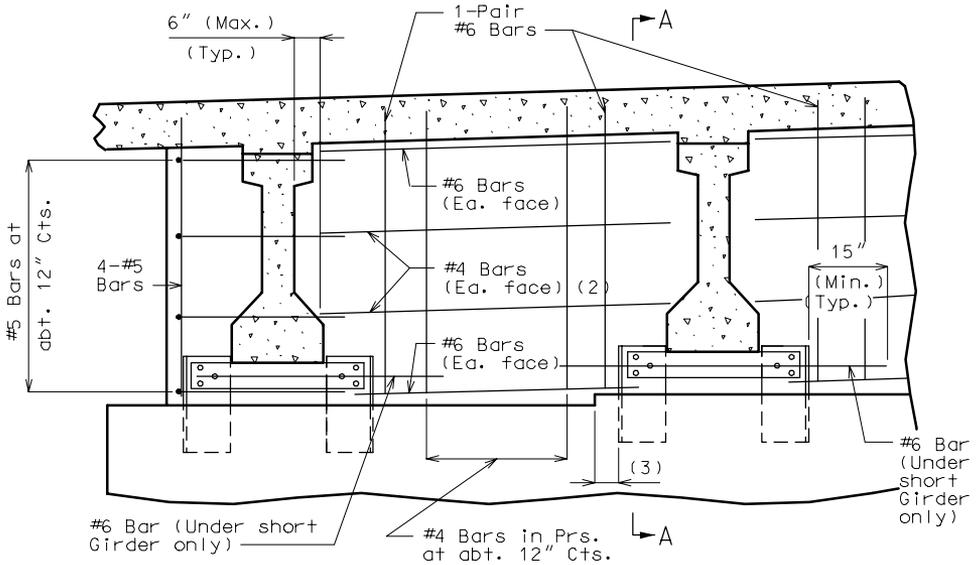


**SKEWS OVER 25°**

#### Closed Intermediate Bent Diaphragms (Cont.) (Change in Girder Height at Fixed Bents) Reinforcement:

Change girder heights within a continuous girder series only when specified on Design Layout or by Structural Project Manager.

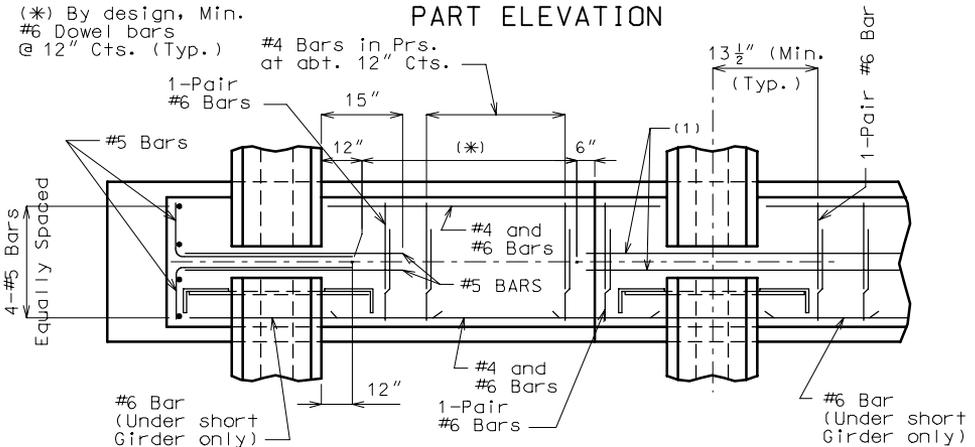
Girder heights can only be changed at fixed bents for continuous series.



### PART ELEVATION

(\*) By design, Min. #6 Dowel bars @ 12" Cts. (Typ.)

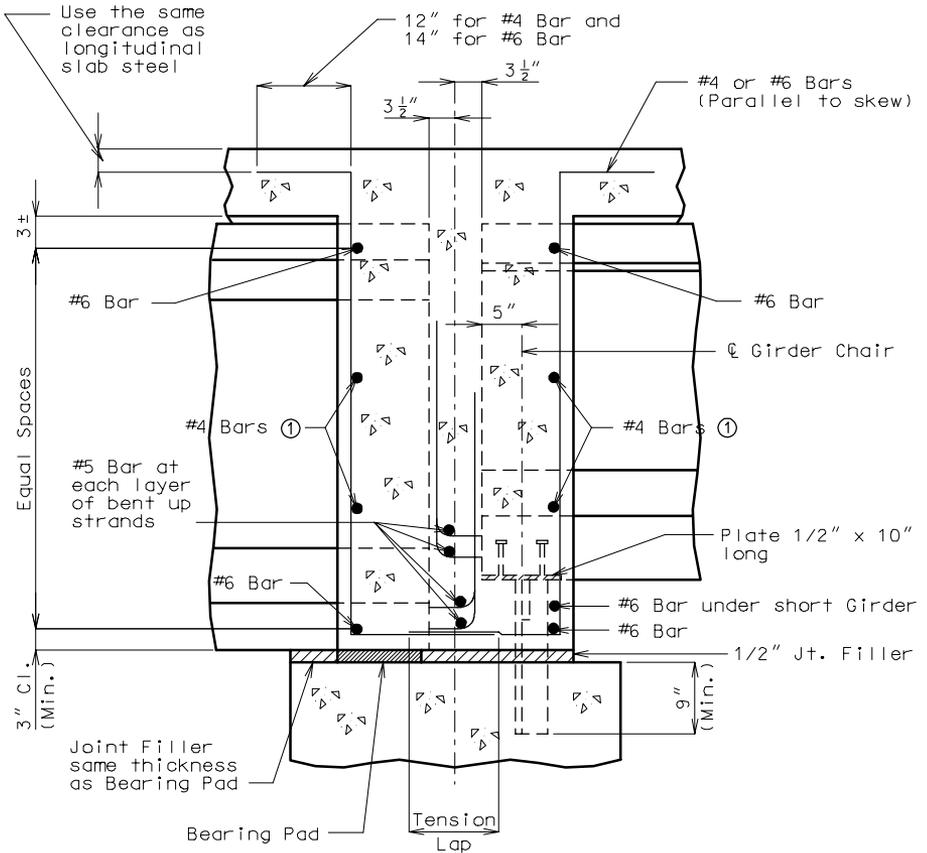
#4 Bars in Prs. at abt. 12" Cts.



### PART PLAN

- (1) At each layer of bent strands.
- (2) For Bulb Tee Girders, use 3-#4 Bars in each Diaphragm face.
- (3) 3" Min. when using beam step.
- (4) By design, Min. #6 @ 12" Cts. dowel bars (Typ.)

Closed Intermediate Bent Diaphragms (Cont.)  
 (Change in Girder Height at Fixed Bents)  
 Reinforcement:

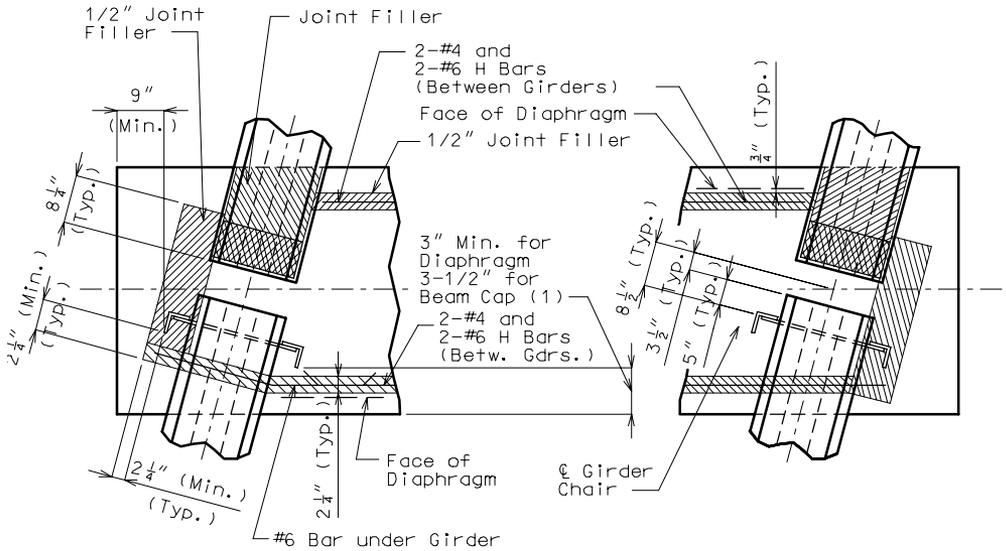


PART SECTION A-A THRU DIAPHRAGM

Note: Girder heights can change a maximum of one Girder type.

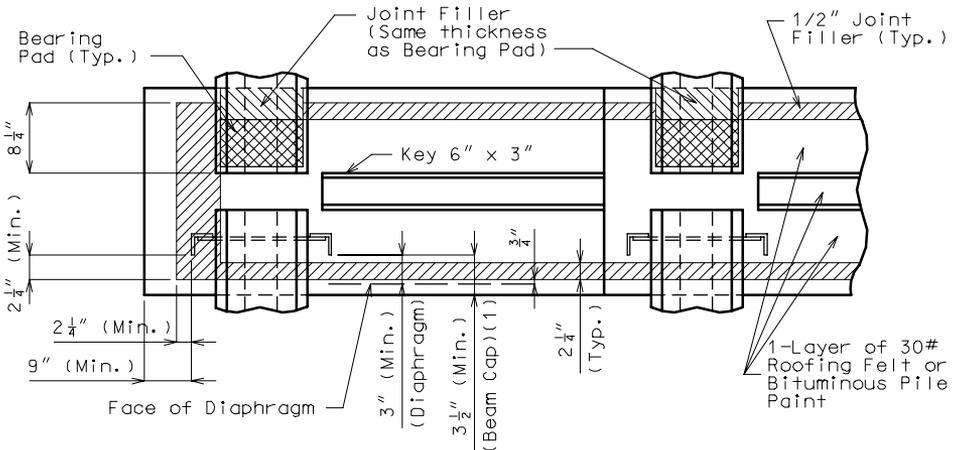
① For Bulb Tee Girders, use 3-#4 Bars in each Diaphragm face.

Closed Intermediate Bent Diaphragms (Cont.)  
 (Change in Girder Height at Fixed Bents)  
 Edge Distance Details:



PART PLAN SKEWED STRUCTURES

NOTE: Field bending may be required for #4 and #6 H Bars In Skewed Structures near short Exterior Girder.

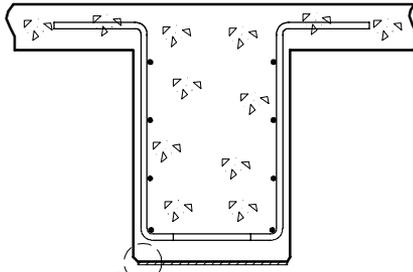


PART PLAN SQUARE STRUCTURES

(1) When Beam width is controlled by Girder Chair clearance, make Diaphragm Flush with Beam Cap.

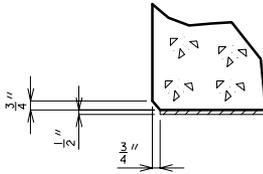


Closed Intermediate Bent Diaphragms (Cont.)  
3/4" Chamfer and 1/2" Joint Filler



Detail "A"

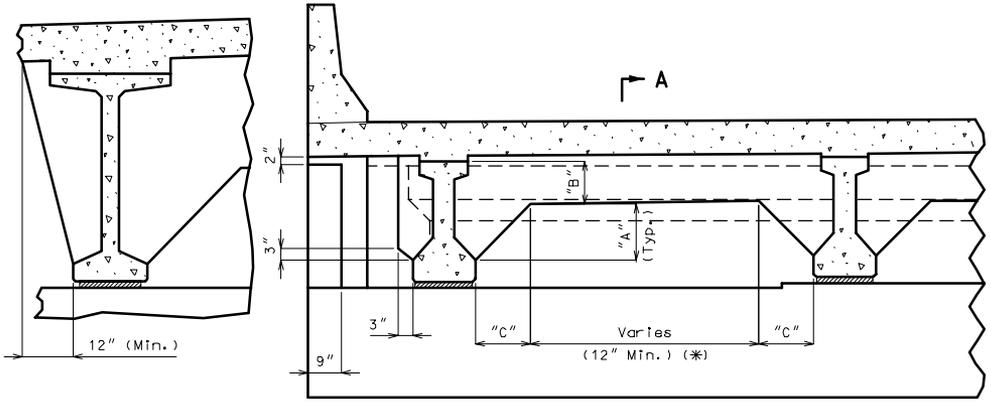
SECTION THRU  
INTERMEDIATE DIAPHRAGMS



DETAIL "A"

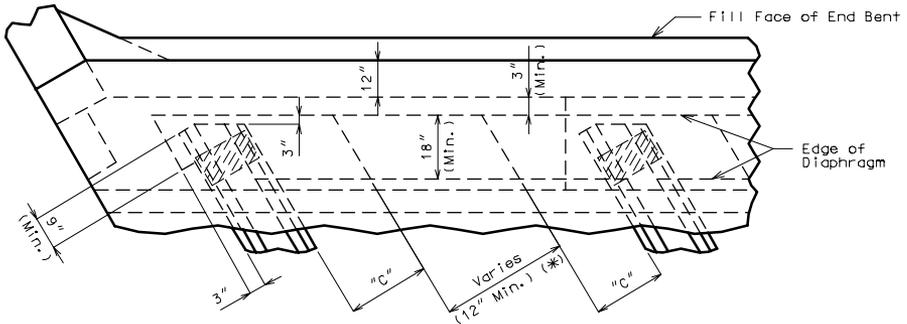
3.14 Non-Integral End Bent Diaphragms  
(End Diaphragm with no Expansion Devices)  
Dimensions:

Details

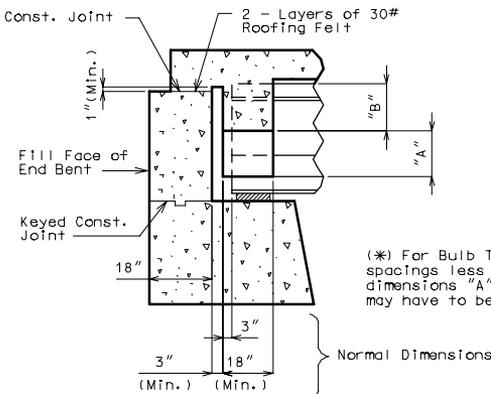


PART ELEVATION FOR BULB TEE GIRDERS

PART ELEVATION NEAR END BENT



PART PLAN NEAR END BENT



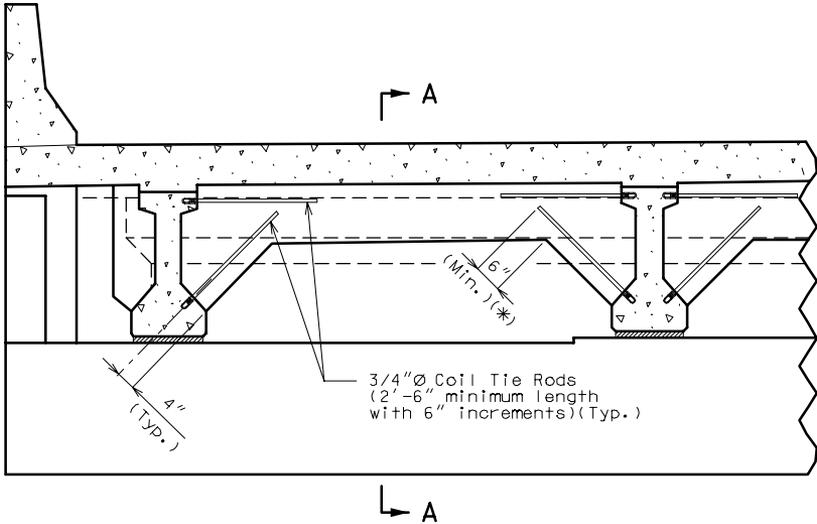
PART SECTION A-A

(\* For Bulb Tee Girder, spacings less than 8'-8" dimensions "A", "B" & "C" may have to be modified.

GIRDER TYPE	DIMENSIONS		
	"A"	"B"	"C"
TYPE "2" 2'-8"	12"	15"	13"
TYPE "3" 3'-3"	17"	15"	19"
TYPE "4" 3'-9"	19"	18"	21"
TYPE "6" 4'-6"	2'-3"	21"	2'-1"
BULB TEE 6'-0 1/2" *	3'-0"	2'-6 1/2"	2'-9"

Non-Integral End Bent Diaphragms (Cont.)  
 (End Diaphragm with no Expansion Device)  
 Coil Tie Rods:

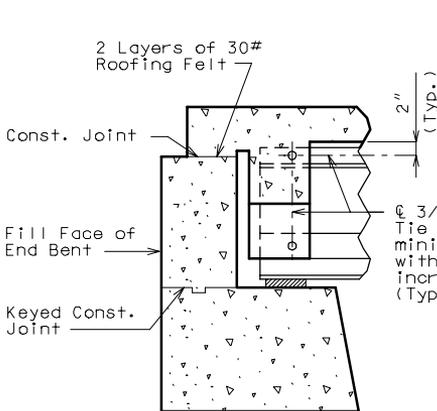
Details



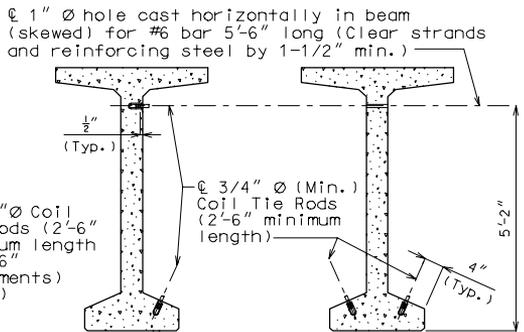
PART ELEVATION NEAR END BENT

NOTE: For location of the Coil Tie Rods in a plan view, see this Section 3.55.3.

(\* ) 6" (Min.) shall be used for all I-Girders and Bulb Tee Girders.



PART SECTION A-A



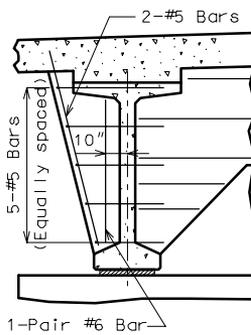
EXTERIOR GIRDERS

INTERIOR GIRDERS

DETAILS OF COIL TIE RODS IN BULB TEE GIRDERS

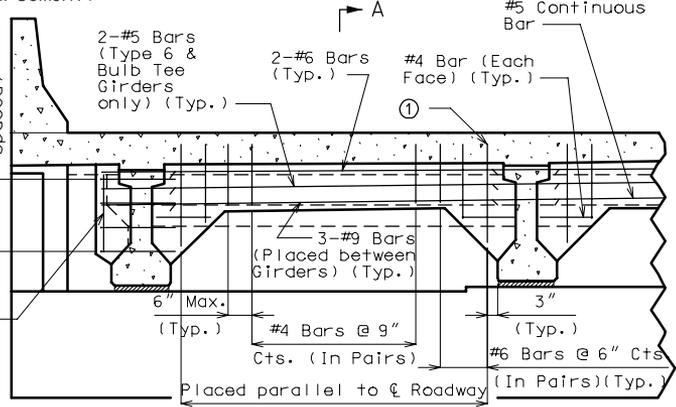
Non-Integral End Bent Diaphragms (Cont.)  
(End Diaphragms with no Expansion Device)  
Reinforcement:

Details



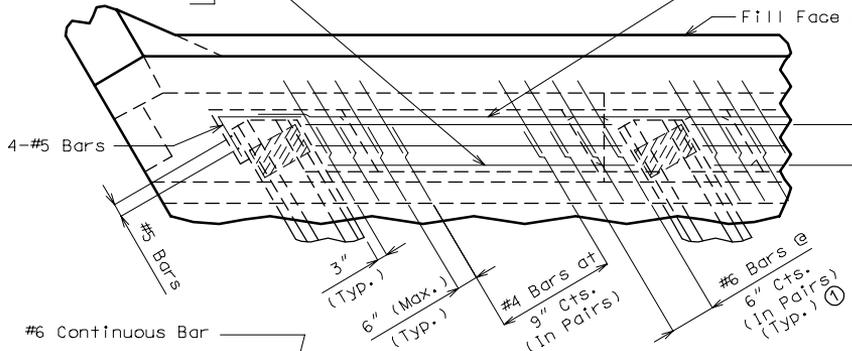
**PART ELEVATION NEAR END BENT FOR BULB TEE GIRDERS**

#6 Bar Btwn. Gdrs.  
#5 Bar Btwn. Gdrs.  
(Type 6 & Bulb Tee Girders only)



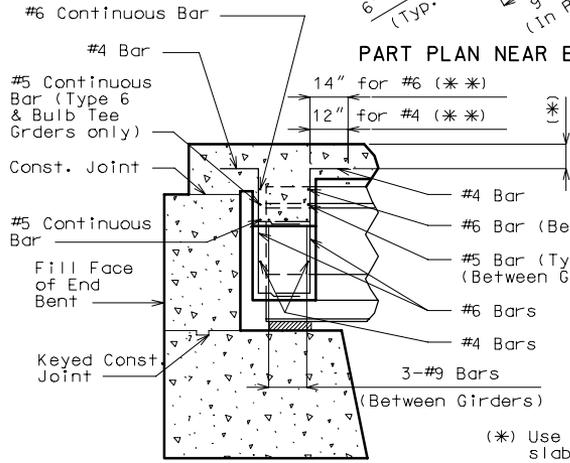
**PART ELEVATION NEAR END BENT**

#5 & #6 Continuous Bar  
Fill Face of End Bent



**PART PLAN NEAR END BENT**

3-#9 Bars in bottom  
(See Section A-A  
for placement) (Typ.)



**PART SECTION A-A**

① For Bulb Tee Girders, the first #6 Bar shall be placed 10" from the  $\epsilon$  of Web (Top Flange will prevent some Bars from extending into the Slab).

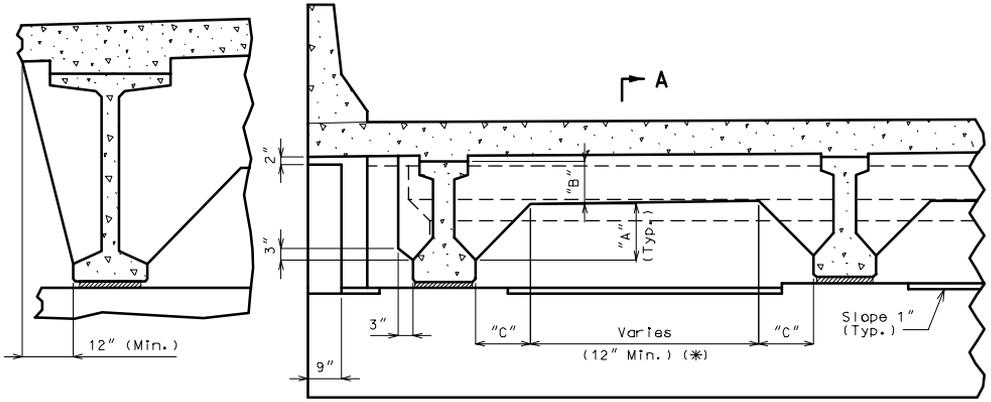
NOTE: Bars across end of girders to be continuous.

(\*) Use the same clearance as longitudinal slab steel.

(\*\*) Show this dimension on Bridge Plan Sheets.

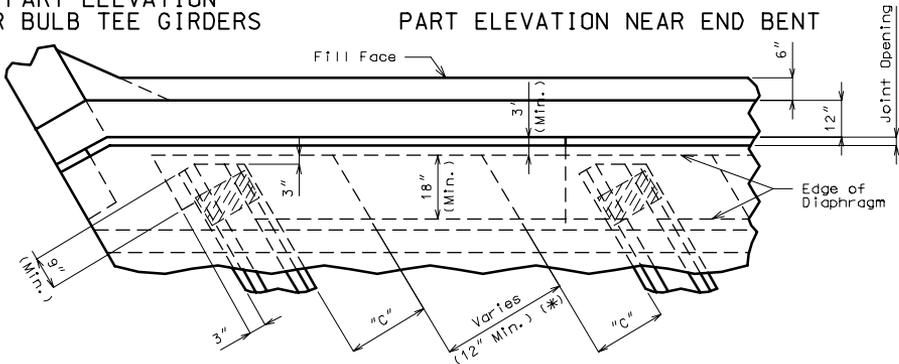
Non-Integral End Bent Diaphragms (Cont.)  
 (End Diaphragms with Expansion Device)  
 Dimensions:

Details

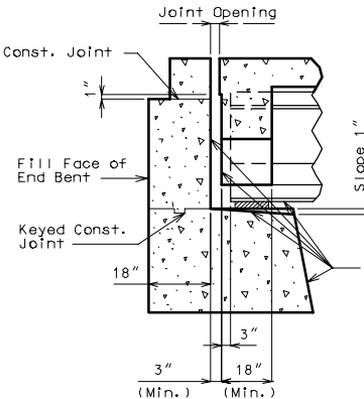


PART ELEVATION FOR BULB TEE GIRDERS

PART ELEVATION NEAR END BENT



PART PLAN NEAR END BENT



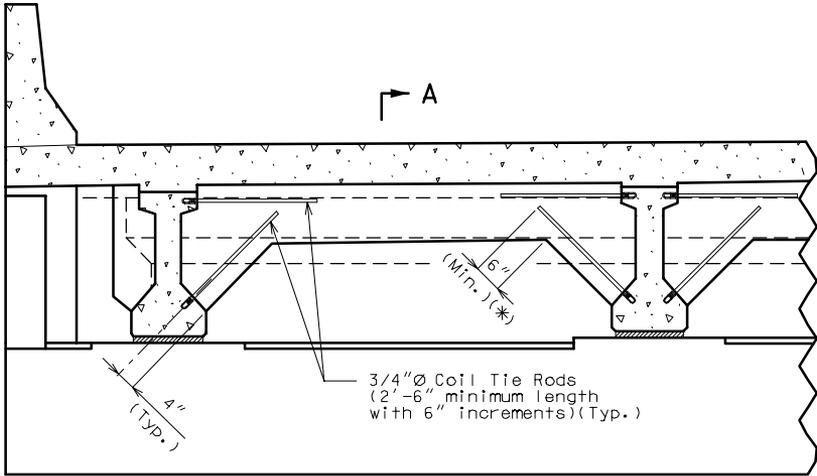
PART SECTION A-A

(\*) For Bulb Tee Girder, spacings less than 8'-8" dimensions "A", "B" & "C" may have to be modified.

GIRDER TYPE	DIMENSIONS		
	"A"	"B"	"C"
TYPE "2" 2'-8"	12"	15"	13"
TYPE "3" 3'-3"	17"	15"	19"
TYPE "4" 3'-9"	19"	18"	21"
TYPE "6" 4'-6"	2'-3"	21"	2'-1"
BULB TEE 6'-0 1/2" *	3'-0"	2'-6 1/2"	2'-9"

Non-Integral End Bent Diaphragms (Cont.)  
 (End Diaphragms with Expansion Device)  
 Coil Tie Rods:

Details

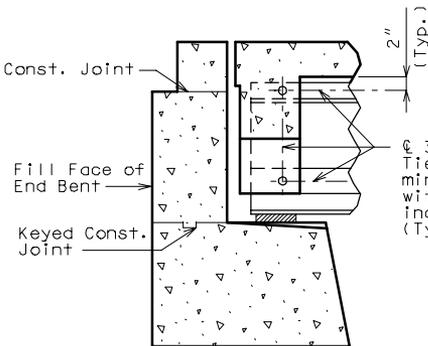


PART ELEVATION NEAR END BENT

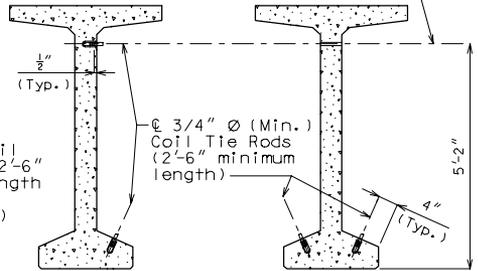
NOTE: For location of the Coil Tie Rods in a plan view, see this Section 3.55.3.

(\*) 6" (Min.) shall be used for all I-Girders and Bulb Tee Girders.

$\varnothing$  1"  $\varnothing$  hole cast horizontally in beam (skewed) for #6 bar 5'-6" long (Clear strands and reinforcing steel by 1-1/2" min.)



PART SECTION A-A



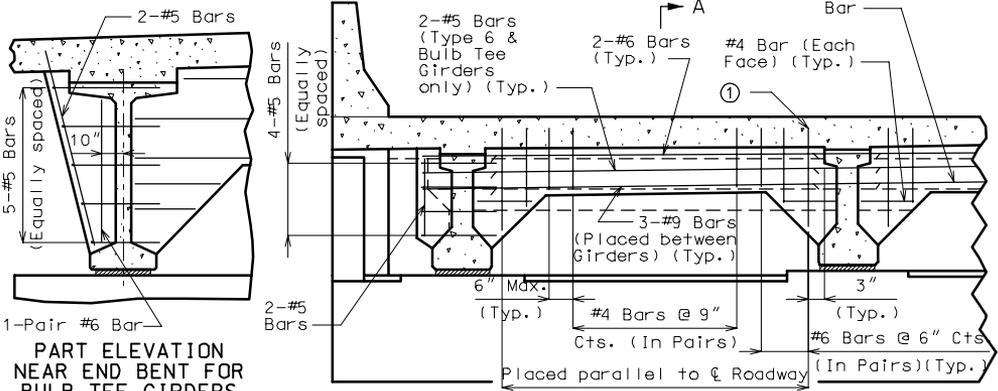
EXTERIOR GIRDERS

INTERIOR GIRDERS

DETAILS OF COIL TIE RODS IN BULB TEE GIRDERS

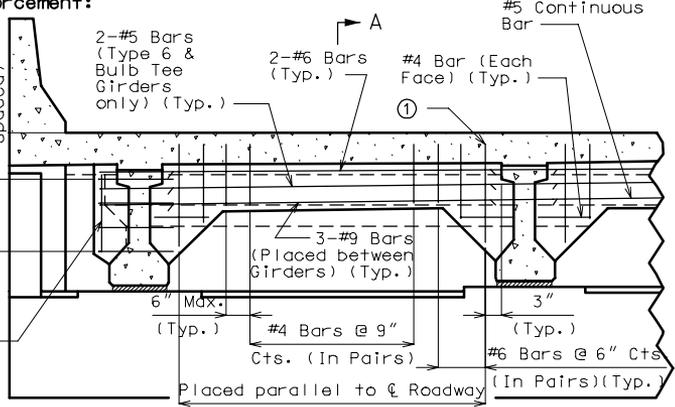
Non-Integral End Bent Diaphragms (Cont.)  
(End Diaphragms with Expansion Device)  
Reinforcement:

Details



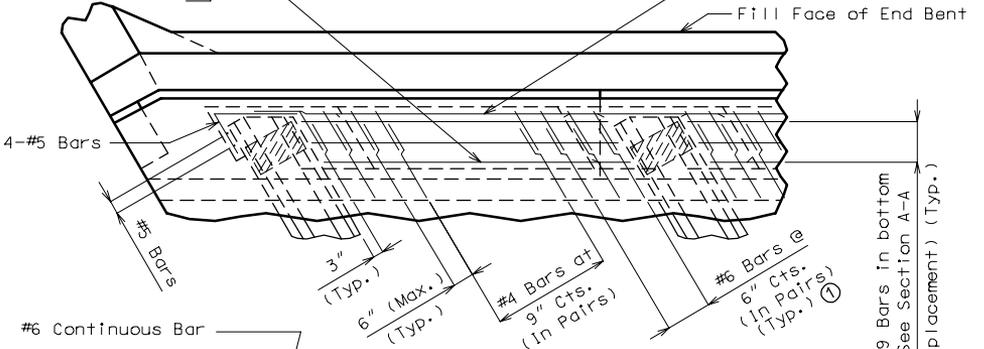
PART ELEVATION  
NEAR END BENT FOR  
BULB TEE GIRDERS

#6 Bar Btwn. Gdrs.  
#5 Bar Btwn. Gdrs.  
(Type 6 & Bulb Tee  
Girders only)



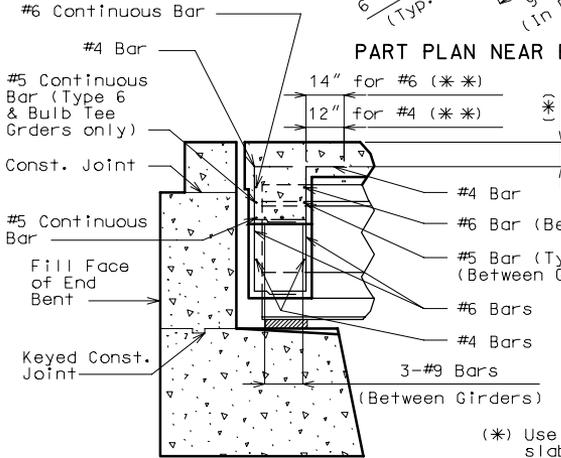
PART ELEVATION NEAR END BENT

#5 & #6 Continuous Bar  
Fill Face of End Bent



PART PLAN NEAR END BENT

3-#9 Bars in bottom  
(See Section A-A  
for placement) (Typ.)



PART SECTION A-A

① For Bulb Tee Girders, the first #6 Bar shall be placed 10" from the  $\phi$  of Web (Top Flange will prevent some bars from extending into the slab).

NOTE: Epoxy Coat all Reinforcing Steel in the End Diaphragms.

NOTE: Bars across end of girders to be continuous.

(\*) Use the same clearance as longitudinal slab steel.

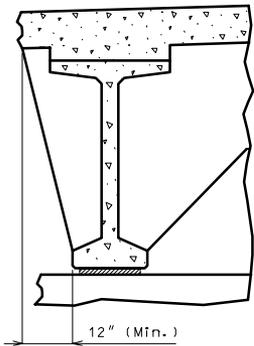
(\*\*) Show this dimension on Bridge Plan Sheets.

### 3.15 Non-Integral Intermediate Bent Diaphragms (End Diaphragms with Expansion Device)

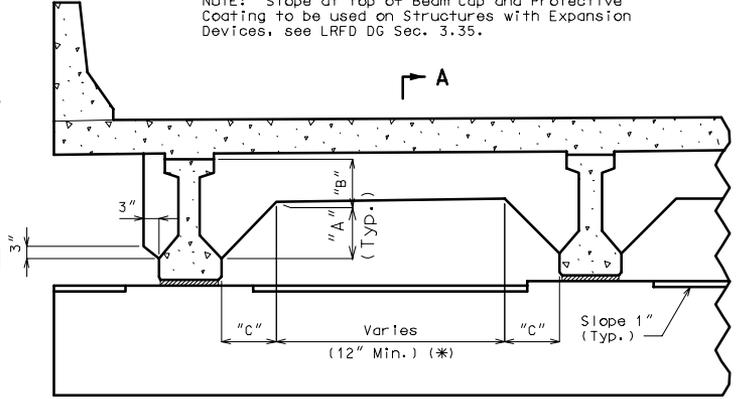
**Details**

**Dimensions:**

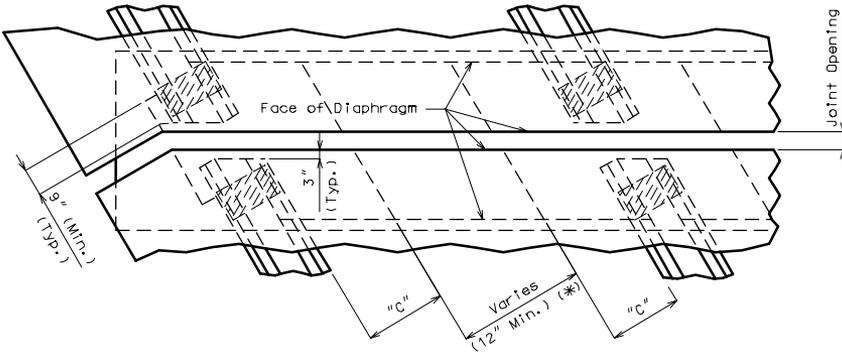
NOTE: Slope at top of Beam Cap and Protective Coating to be used on Structures with Expansion Devices, see LRFD DG Sec. 3.35.



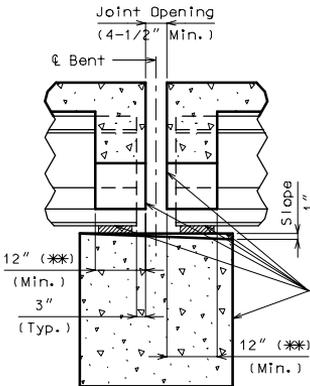
**PART ELEVATION FOR BULB TEE GIRDERS**



**PART ELEVATION NEAR INT. BENT**



**PART PLAN NEAR INT. BENT**



**PART SECTION A-A**

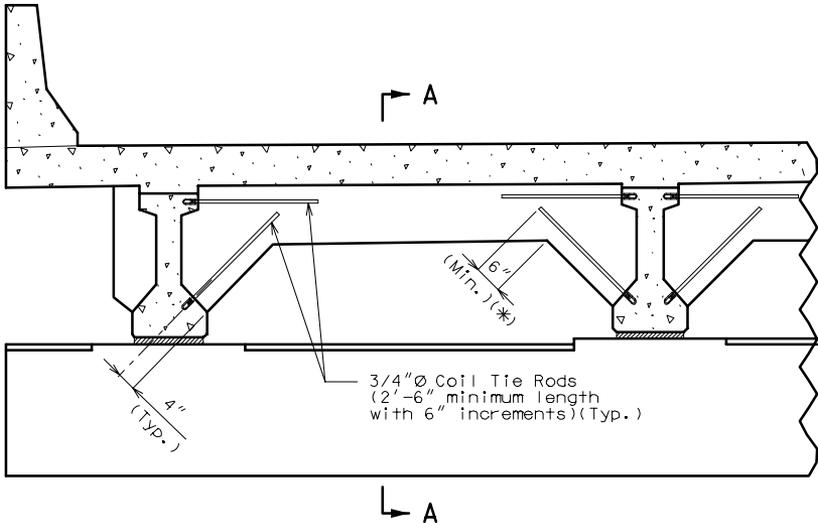
(\*) For Bulb Tee Girder, spacings less than 8'-8" dimensions "A", "B" & "C" may have to be modified.

(\*\*) Make sure the Diaphragm is wide enough to provide enough cover for the Coll Tie Rods.

Seal Diaphragm, bottom of Girder, top of Beam and front face of Beam with Protective Coating - Concrete Bents and Piers (Urethane or Epoxy) (See Sec 711)

GIRDER TYPE	DIMENSIONS		
	"A"	"B"	"C"
TYPE "2" 2'-8"	12"	15"	13"
TYPE "3" 3'-3"	17"	15"	19"
TYPE "4" 3'-9"	19"	18"	21"
TYPE "6" 4'-6"	2'-3"	21"	2'-1"
BULB TEE 6'-0 1/2" *	3'-0"	2'-6 1/2"	2'-9"

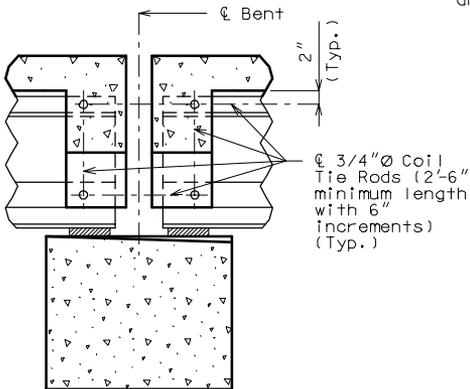
Non-Integral Intermediate Bent Diaphragms (Cont.)  
 (End Diaphragms with Expansion Device)  
 Coil Tie Rods:



PART ELEVATION NEAR INT. BENT

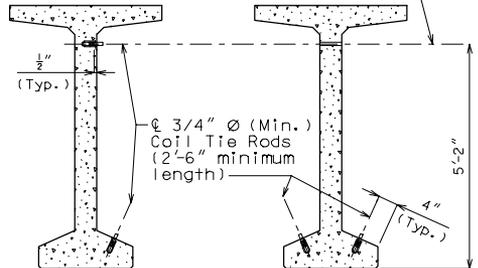
NOTE: For location of the Coil Tie Rods in a plan view, see LRFD DG Sec. 3.55.3.

(\*) 6" (Min.) shall be used for all I-Girders and Bulb Tee Girders.



PART SECTION A-A

$\varnothing$  1"  $\varnothing$  hole cast horizontally in beam (skewed) for #6 bar 5'-6" long (Clear strands and reinforcing steel by 1-1/2" min.)



EXTERIOR GIRDERS

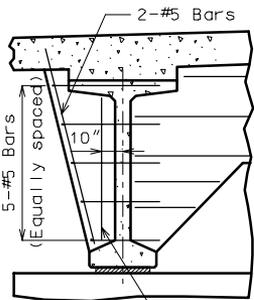
INTERIOR GIRDERS

DETAILS OF COIL TIE RODS IN BULB TEE GIRDERS

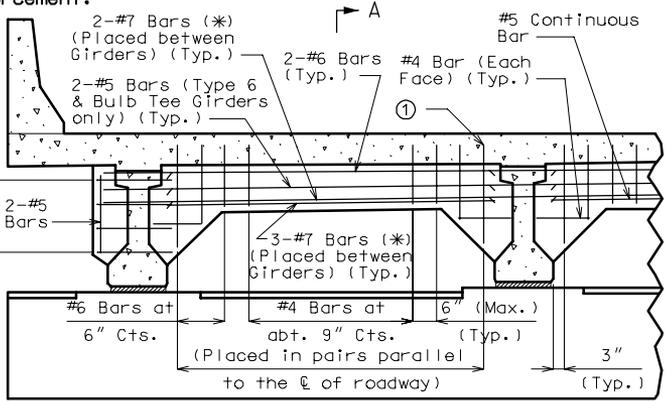
# LRFD Bridge Design Guidelines

## Prestressed Concrete I-Girders - Section 3.55

### Non-Integral Intermediate Bent Diaphragms (Cont.) Details (End Diaphragm with Expansion Device) Reinforcement:

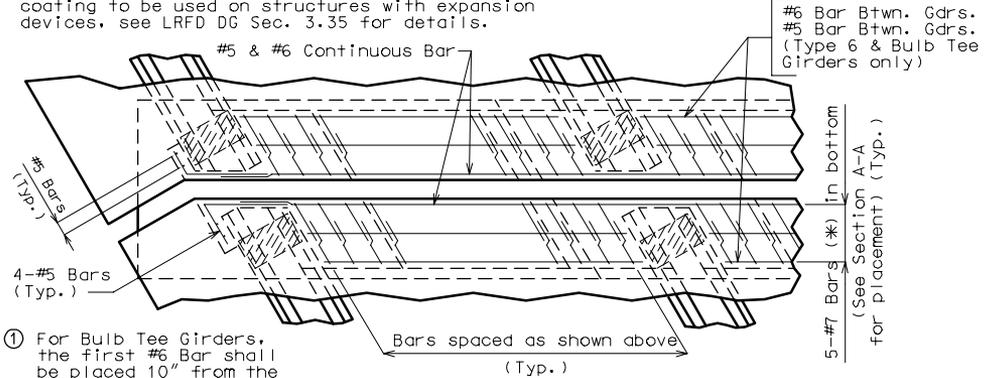


**PART ELEVATION NEAR INT. BENT FOR BULB TEE GIRDERS**

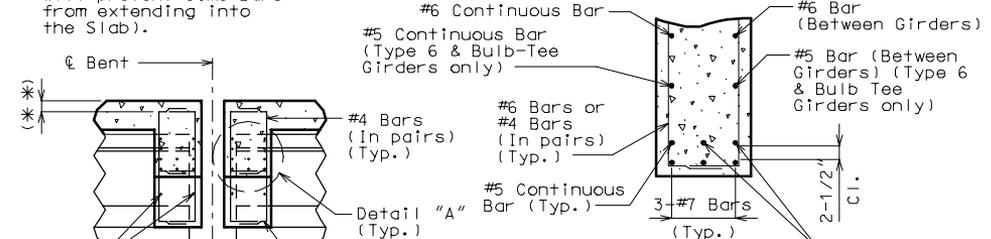


**PART ELEVATION NEAR INT. BENT**

**NOTE:**  
Slope at top of beam cap and protective coating to be used on structures with expansion devices, see LRFD DG Sec. 3.35 for details.

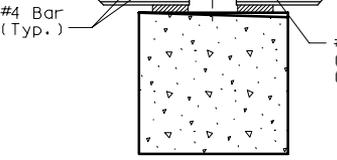


**PART PLAN NEAR INT. BENT**



**DETAIL "A"**

(\*) See Detail "A" for the placement of reinforcement.  
(\*\*) Use the same clearance as longitudinal slab steel.



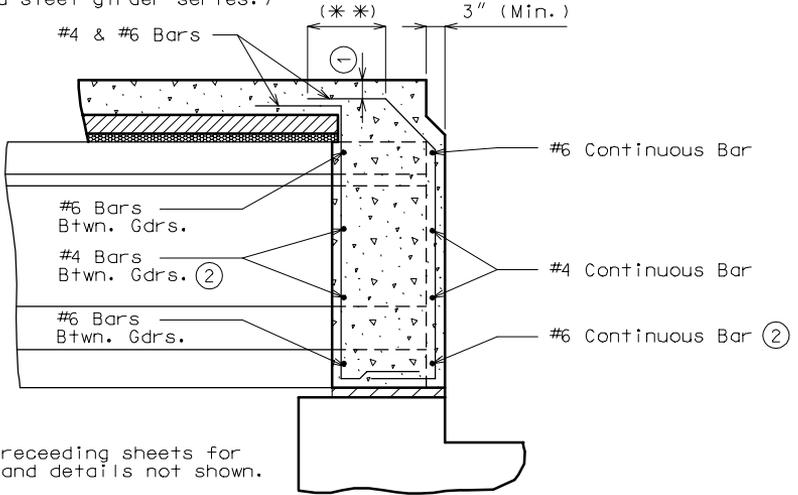
**PART SECTION A-A**

**NOTE:**  
Epoxy coat all reinforcing steel in the end diaphragms.

Non-Integral Intermediate Bent Diaphragms (Cont.) Details  
 (End Diaphragm with Finger Plate Expansion Device)  
 Diaphragm Reinforcements:

CLOSED DIAPHRAGM:

(NOTE: Use only when expansion device connects prestress girder series and steel girder series.)

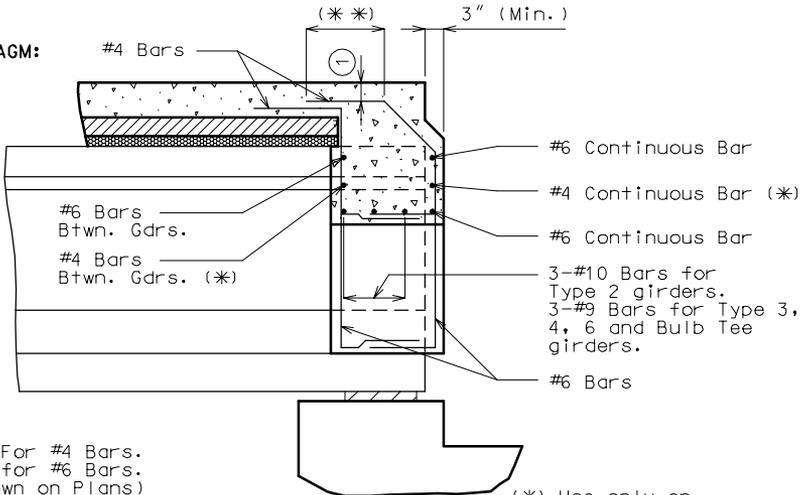


NOTE: See preceding sheets for bar spacing and details not shown.

A protective coating shall be applied to concrete surface exposed to drainage from roadway. Indicate surface to be coated on plans. Epoxy coat all reinforcing steel in the end diaphragms.

② For Bulb Tee Girders use 3-#4 Bars in each face.

OPEN DIAPHRAGM:



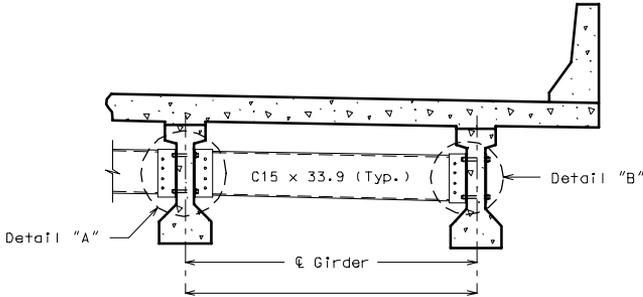
(\* \*) 12" For #4 Bars.  
 14" for #6 Bars.  
 (Shown on Plans)

(\*) Use only on Type 6 Girder

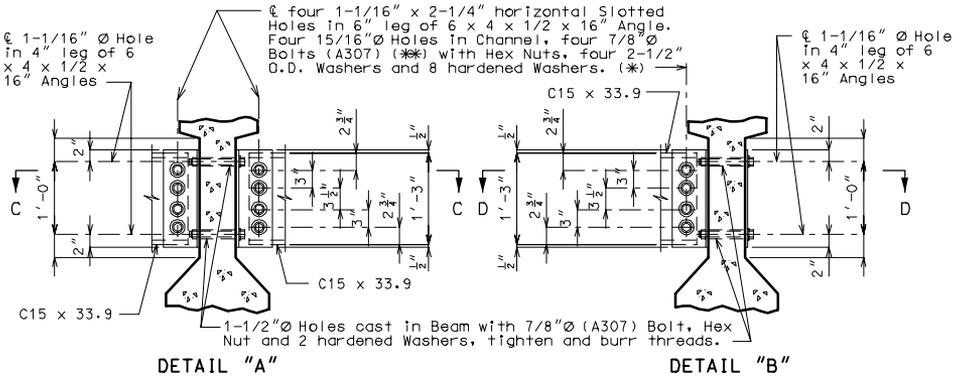
① Use the same clearance as longitudinal slab steel.

3.16 Intermediate Diaphragms  
(Use Steel Intermediate Diaphragm  
for Prestress Spans over 50 feet)

Details



PART SECTION SHOWING  
INTERMEDIATE DIAPHRAGMS

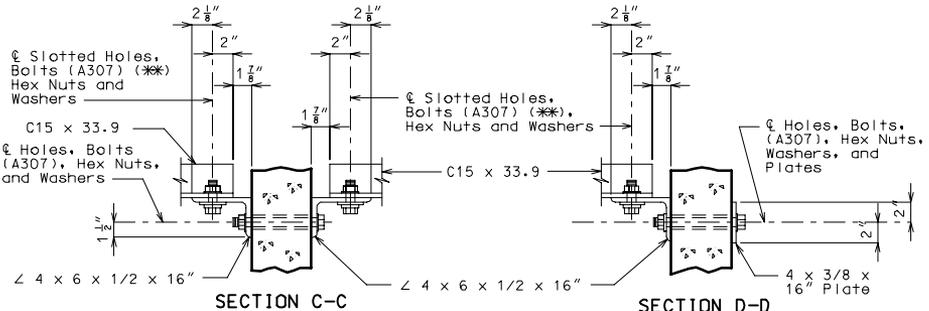


(\*) In lieu of 2-1/2" O.D. washers, contractor may substitute a 3/16" (Min. thickness) plate with four 15/16" Ø holes and one hardened washer per bolt.

(\*\*) Bolts shall be tightened to provide a tension of one-half that specified in Sec 712 for high strength bolt installation. A325 bolts may be substituted for and installed in accordance with the requirements for the specified A307 bolts.

NOTE: Use Detail "A" at interior girder for diaphragms straight in line across structure. (Use straight diaphragm normal to girders for skews thru 20°).

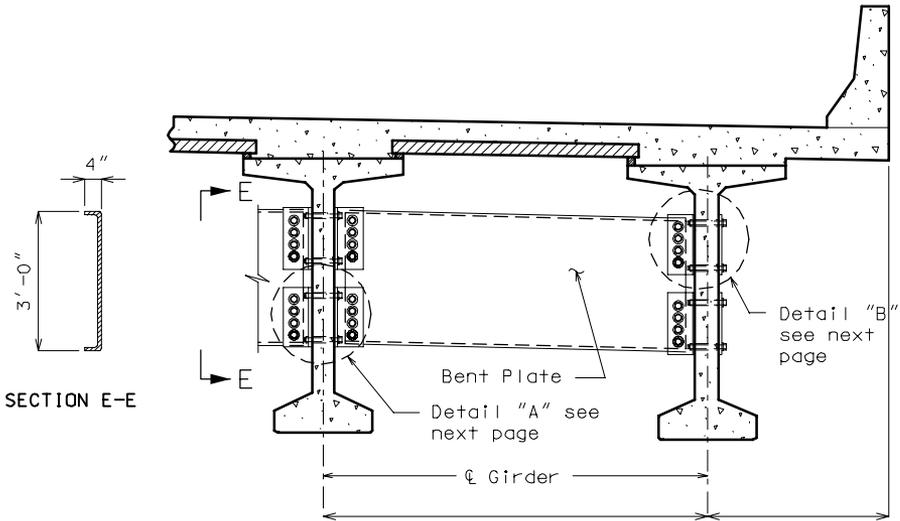
Use Detail "B" for exterior girder and interior girder for diaphragms stepped across structure. (Use stepped diaphragm for skews over 20°).



Note: For General Notes, (\*) and (\*\*), see LRFD DG Sec. 4.0 H.

Intermediate Diaphragms (Cont.)  
 (Use Steel Intermediate Diaphragm  
 for Prestress Spans over 50 Feet)

Details



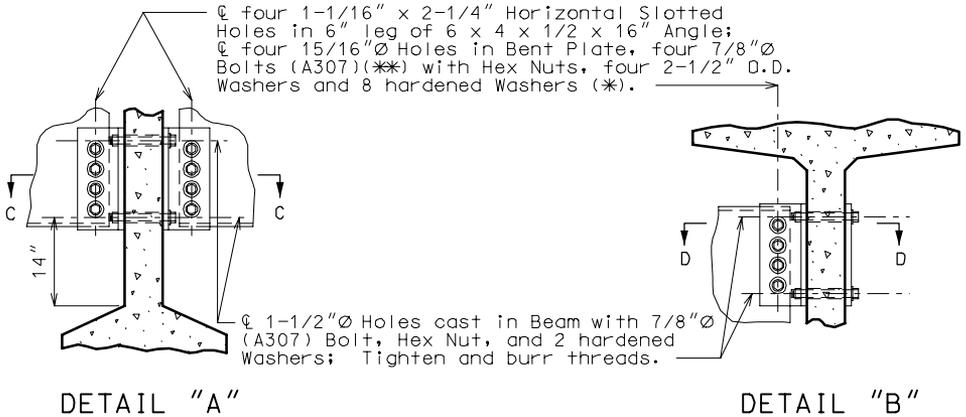
PART SECTION SHOWING  
 INTERMEDIATE DIAPHRAGMS

Bulb Tee spans of 90 feet or less require one intermediate diaphragm per span. Bulb Tee spans of over 90 feet require two intermediate diaphragms per span (spaced equally as allowed by clearance to harped strands). Maximum spacing is 50 ft.

The detailer shall check that the 1-1/2 inch  $\varnothing$  holes for the diaphragms shown on the design plans will provide a minimum clearance of at least 1-1/2 inches to any prestressing strands.

Intermediate Diaphragms (Cont.)  
 (Use Steel Intermediate Diaphragm  
 for Prestress Spans over 50 Feet)

Details

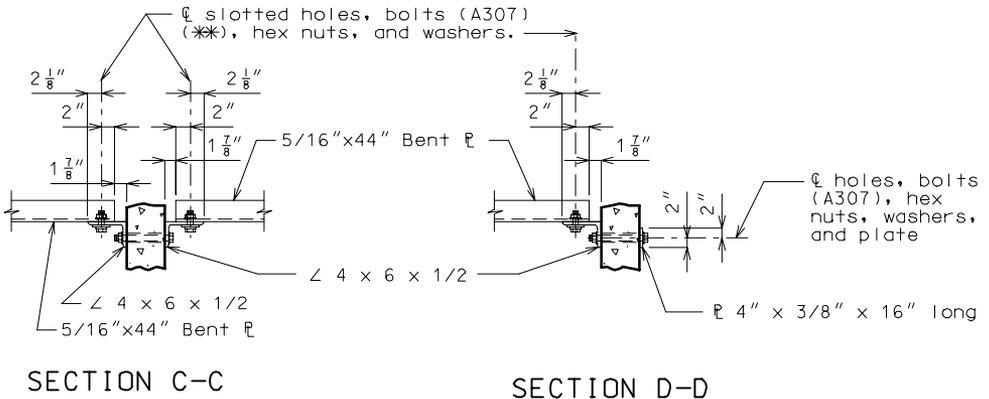


(\*) In lieu of 2-1/2" O.D. washers, the contractor may substitute a 3/16" (min. thickness) plate with four 15/16"  $\varnothing$  holes and one hardened washer per bolt.

(\*\*) Bolts shall be tightened to provide a tension of one-half that specified by Sec 712 for high strength bolt installation. A325 bolts may be substituted for and installed in accordance with the requirements for the specified A307 bolts.

Note: Use Detail "A" at interior girders for diaphragms straight in line across structure. (Use straight diaphragms normal to girders for skewers thru 20°).

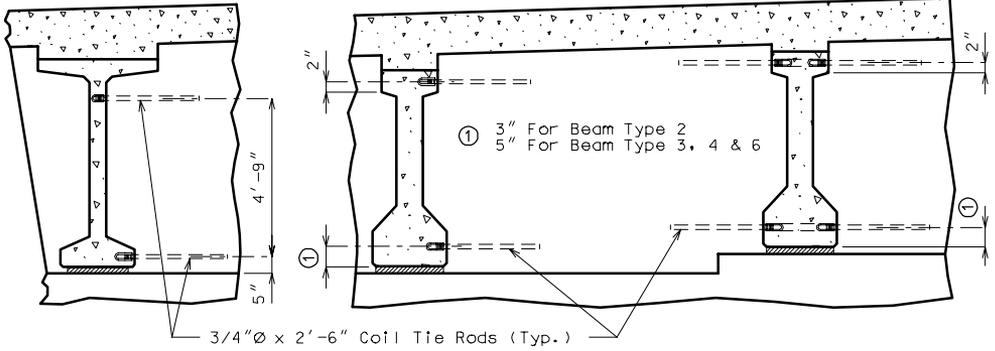
Use Detail "B" for exterior girders and interior girders for diaphragms stepped across structure. (Use stepped diaphragms for skewers over 20°).



Note: For General Notes, (\*) and (\*\*), see LRFD DG Sec. 4.0 H.

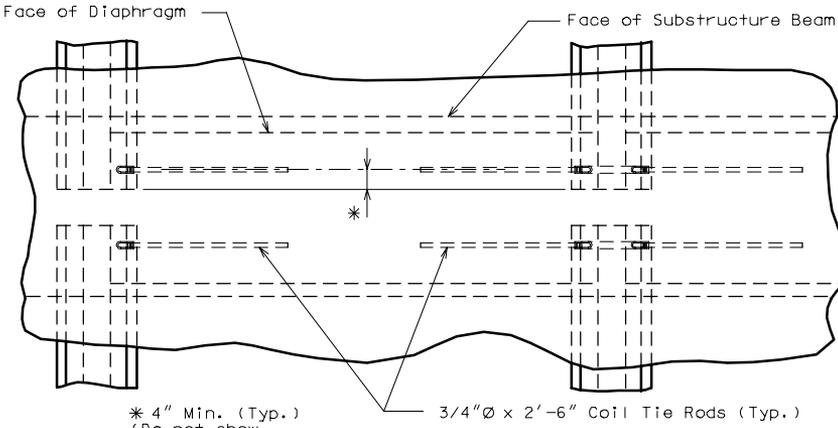
3.17 Coil Ties

Details

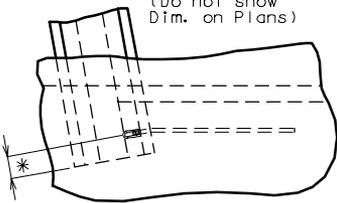


PART ELEVATION FOR BULB-TEE GIRDERS

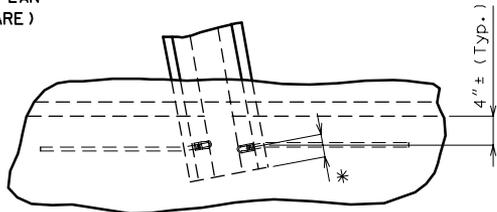
PART ELEVATION



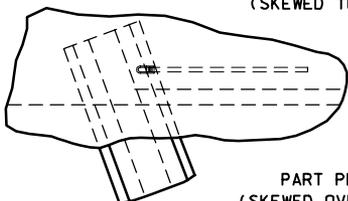
PART PLAN (SQUARE)



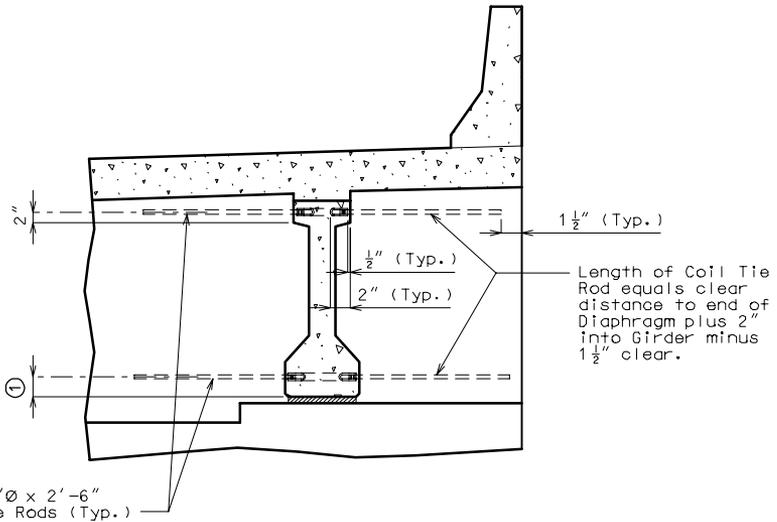
PART PLAN (SKEWED TO 20°)



PART PLAN (SKEWED OVER 20°)



Coil Ties (Cont.)



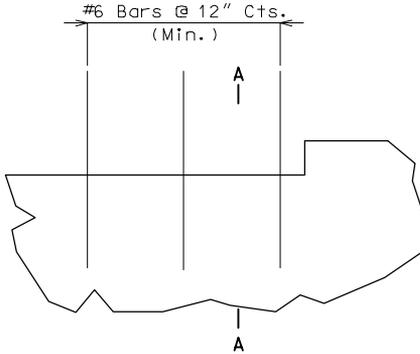
EXTERIOR GIRDER AT END BENT

- ① 3" For Beam Type 2
- 5" For Beam Type 3, 4 & 6

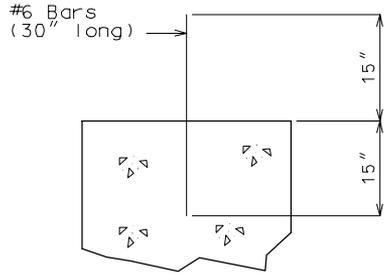
NOTE: See previous page for location of Coil Tie Rods on Bulb Tee girders.

3.18 Dowel Bars

Details



PART ELEVATION  
(FIXED BENT)

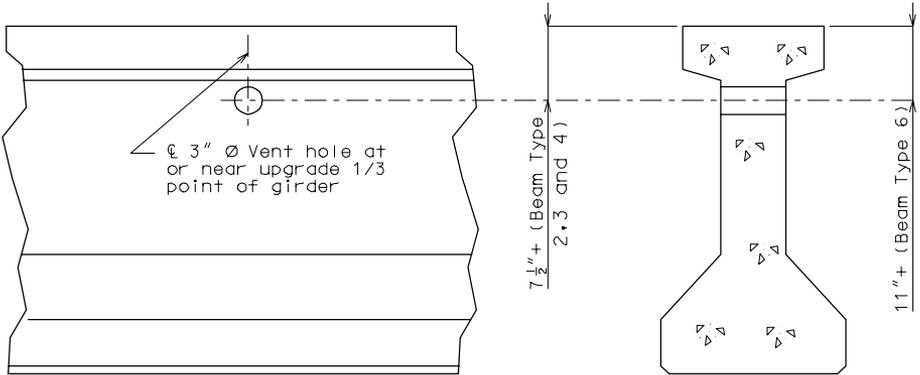


SECTION A-A

Dowel bars shall be used for all fixed intermediate bents under prestressed superstructures.

Dowel bars shall be determined by design. See appropriate Substructure Section of LRFD Bridge Design Guidelines. (minimum #6 Bars @ 12" Cts.)

Note: Use vent holes on all stream crossing structures.



PART ELEVATION OF GIRDER

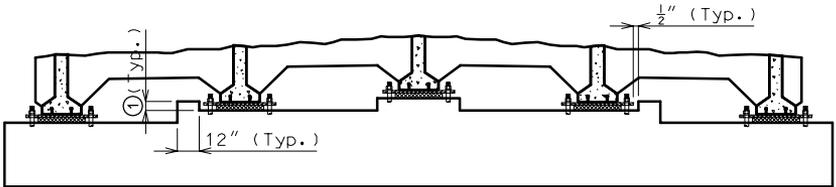
PART SECTION NEAR VENT HOLE

Note: Place vent holes at or near upgrade 1/3 point of girders and clear reinforcing steel or strands by 1-1/2" minimum and steel intermediate diaphragms bolt connection by 6" minimum.

3.20 Shear Blocks

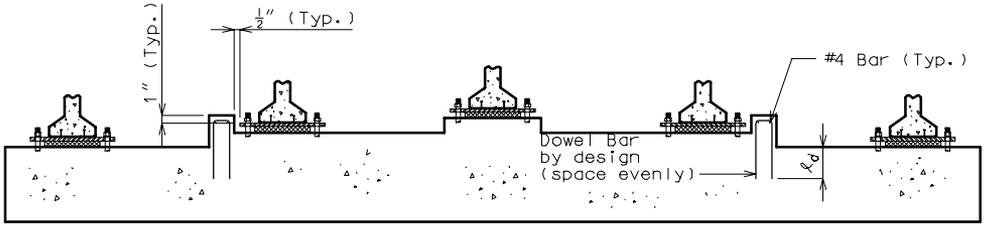
Details

A minimum of two Shear Blocks 12" wide x ① high by width of diaphragm, will be detailed at effective locations on open diaphragm bent caps when adequate structural restraint cannot be provided for with anchor bolts.

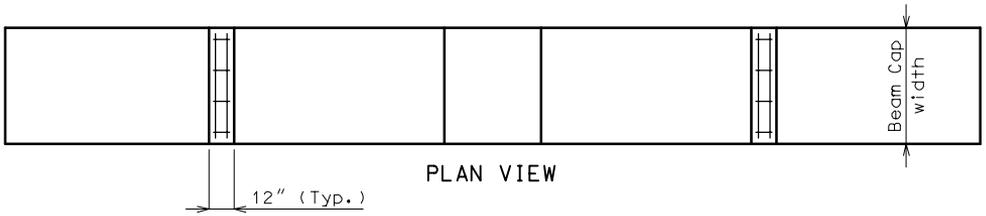


ELEVATION VIEW

- ① Height of shear block shall extend a minimum of 1" above the top of the sole plate.



ELEVATION VIEW

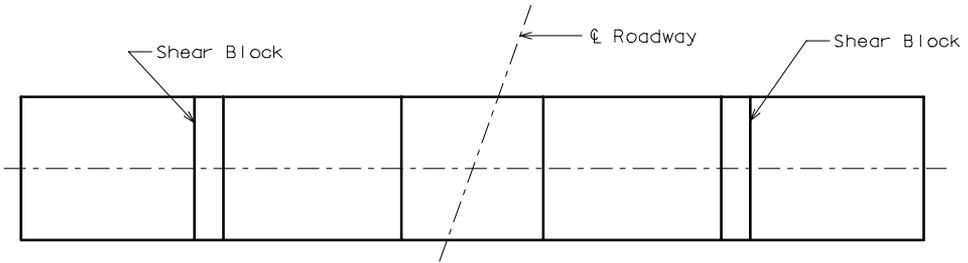


PLAN VIEW

**Note:**

Shear blocks shall be used at bents with open diaphragms when anchor bolts can not be designed to resist earthquake loading.

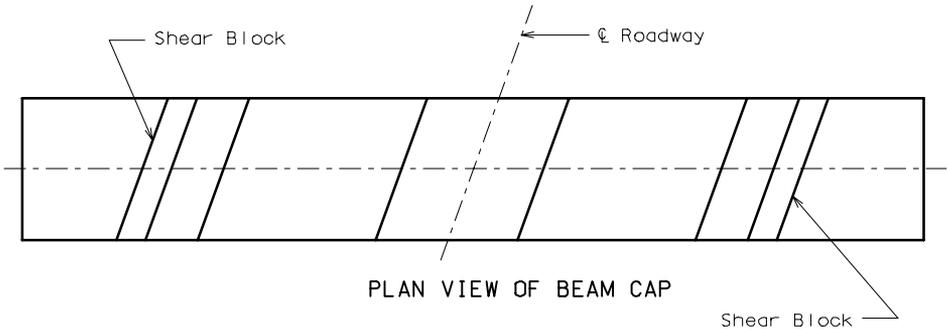
Shear Blocks (Cont.)



PLAN VIEW OF BEAM CAP

EXPANSION BENTS WITH OPEN DIAPHRAGMS

Note: For Expansion Bents with open diaphragms, the steps or Shear Block (if applicable) should be normal to the length of cap.



PLAN VIEW OF BEAM CAP

EXPANSION BENTS WITH CLOSED DIAPHRAGMS

Note: For Closed Diaphragm Expansion Bents, the steps or haunches shall be detailed parallel to the centerline of roadway.

For Integral End Bents the steps may be skewed due to stirrups being placed parallel to centerline of roadway.

Shear Blocks for Expansion Bents with Closed Diaphragms shall be detailed parallel to the centerline of roadway. Shear Blocks used in conjunction with sole plates and anchor bolts shall be detailed parallel to the edge of sole plate.

# LRFD Bridge Design Guidelines

### 3.21 Miscellaneous

### Details

#### Dimensional Tolerances – I Girders (For Tee Girders & Deck Panels, see Sec 1029)

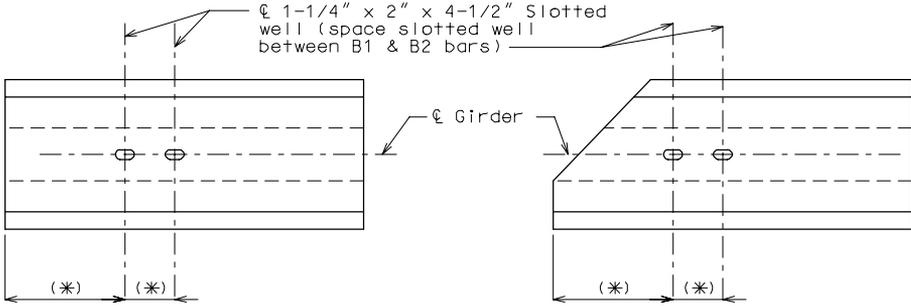
Note: The following dimensional tolerances will be required (Also see Sec 1027 & 1029)

Length of beam	$\pm 1/8$ inch per 10 feet of beam length, but not greater than $3/4$ inch.
Width (flanges, web and fillets)	+ $3/8$ inch, - $1/4$ inch.
Depth (flanges, web and fillets)	$\pm 1/4$ inch.
Depth (overall)	+ $1/2$ inch, - $1/4$ inch.
Horizontal alignment (Deviation from a straight line parallel to centerline of member)	$1/2$ inch max., to 40-foot lengths $3/4$ inch max., 40 to 60-foot lengths 1 inch max., 60-foot or greater lengths.
Camber (Deviation from design camber within 7 days of strand release)	$\pm 1/2$ inch, to 80-foot lengths $\pm 1$ inch, greater than 80-foot lengths.
Stirrup bars (projection above top of beam)	$\pm 3/4$ inch.
Stirrup bars (longitudinal spacing)	$\pm 2$ inches
Tendon position	$\pm 1/4$ inch center of gravity of strand group and individual tendons.
Position of deflection points for deflected strands	$\pm 6$ inches, longitudinal.
Position of lifting devices	$\pm 6$ inches, longitudinal.
Side inserts (centerline to centerline and centerline to end)	$\pm 1/2$ inch.
Coil Inserts (Centerline to centerline and centerline to end)	$\pm 2$ inches horizontal, except must be 3 inches or more from end of beam and within reinforcement cage of bent, $\pm 1$ inch vertical.
Slab Drain Inserts	$\pm 1/2$ inch from designated location, engineer may approve location $\pm 6$ inches from design, multiple inserts for single drain must be within $\pm 1/2$ inch of vertical line.
Exposed beam ends (deviation from square or designated skew)	$\pm 1/4$ inch horizontal, $\pm 1/8$ inch vertical per foot of beam height.
Bearing area (deviation from plane)	$\pm 1/8$ inch.
Bearing plates (centerline to centerline)	$\pm 1/8$ inch per 10 feet of beam length, but not greater than $3/4$ inch.
Bearing plates (centerline to end of beam)	$\pm 1/2$ inch.
Diaphragm Hole Location	$\pm 1 1/2$ inches for centerline of group $\pm 1/2$ inch within group.

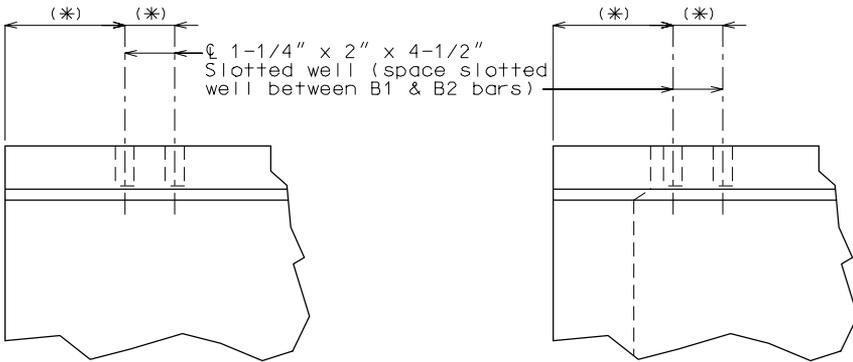
Miscellaneous (Cont.)  
Expansion Device Support Slots

Details

Used with preformed compression joint seal, flat plate, strip seal or finger plate expansion devices.



PART PLAN OF P/S CONC. I-GIRDER @ EXP. DEVICE END



PART ELEVATION OF P/S CONC. I-GIRDER @ EXP. DEVICE END

(\*) Show these dimensions on the P/S concrete girder sheet.

